Appendix A – Point Sources

Contents

Tables

Figures

A.1 Introduction

Both Montana and Wyoming have issued surface water discharge permits to facilities in the Tongue River watershed. This appendix is intended to provide a summary of those facilities to support water quality assessments and modeling efforts for the Tongue River, Tongue River Reservoir, Hanging Woman Creek, Otter Creek, and Pumpkin Creek. The various types of facilities in the Tongue River watershed are discussed below (Sections A.2 and A.3), followed by a summary of the permits and outfalls included in the LSPC model. The following sections also include information about the facility's history (e.g., inception, major changes, etc), permit limits, outfall locations, and outfall monitoring data.

A.2 Montana Permits

There are currently 7 MPDES permitted point sources that discharge to streams in the Tongue River watershed, Montana:

- Decker Coal Company West Mine – MT0000892
- Decker Coal Company East Mine – MT0024210
- Spring Creek Coal Company – MT0024619
- Spring Creek Coal Company (Stormwater Runoff) – MTR300198
- Pinnacle Gas Resources Coal Creek CBM Field – MT0030660
- Fidelity Exploration and Production Company Tongue River Project – MT0030457
- Fidelity Exploration and Production Company Tongue River Project Treatment Facility – MT0030724

The following sections discuss these facilities in more detail, including outfall locations, flows, water quality, and permit limits. In addition to the MPDES permitted point sources, the Birney and Ashland wastewater treatment lagoons are discussed.

A.2.1 Coal Mines

Three coal mines are permitted to discharge pit water and stormwater runoff to streams in the Tongue River watershed, Montana – Decker East and West, and the Spring Creek coal mines. All three have permits to discharge pit water to settling ponds that eventually flow into the Tongue River Reservoir. Spring Creek also has a MPDES stormwater permit, which allows for stormwater runoff to be discharged to a settling pond and eventually the Tongue River Reservoir. The following sections further describe the facilities.

A.2.1.1 Decker Coal Company West Mine (MT0000892) and East Mine (MT0024210)

The Decker Coal Company East and West Coal Mines are located approximately three miles northeast of the Town of Decker, Montana on the southeast and southwest sides of the Tongue River Reservoir, respectively (Figure A-1). Open pit mine operations began in the early 1970s, with the first shipment of coal occurring in 1972 (Kiewit, 2006). At the present, both mines are still operational.

The West Mine is currently permitted by Montana DEQ (MPDES Permit # MT0000892) to discharge groundwater (i.e., pit water) and stormwater runoff to two outfalls: 001-78 and 007-89 (MDEQ, 2006a). Figure A-1 shows the location of the outfalls. Each outfall discharges to a settling pond, which then discharges to the Tongue River Reservoir. Two other outfalls, 008-92 and 010, discharge surface runoff from spoils stockpiles and stripped areas to two settling ponds that discharge to Pearson Creek and then the Tongue River Reservoir. Outfall number 005-80 is permitted to discharge wastewater from the

preparation plant and stormwater to a settling pond that discharges to the Tongue River Reservoir. MPDES monitoring for all outfalls is for water leaving the settling ponds and discharging to unnamed tributaries to the Tongue River Reservoir.

The East Mine is currently permitted by Montana DEQ (MPDES Permit # MT0024210) to discharge groundwater (i.e., pit water) and stormwater runoff to one outfall (outfall 002-89) (MDEQ, 2006b) (Figure A-1). Treatment consists of a settling pond, which then discharges to the Tongue River Reservoir. No other outfalls are currently permitted. MPDES monitoring for all outfalls is for water leaving the settling ponds and discharging to unnamed tributaries to the Tongue River Reservoir.

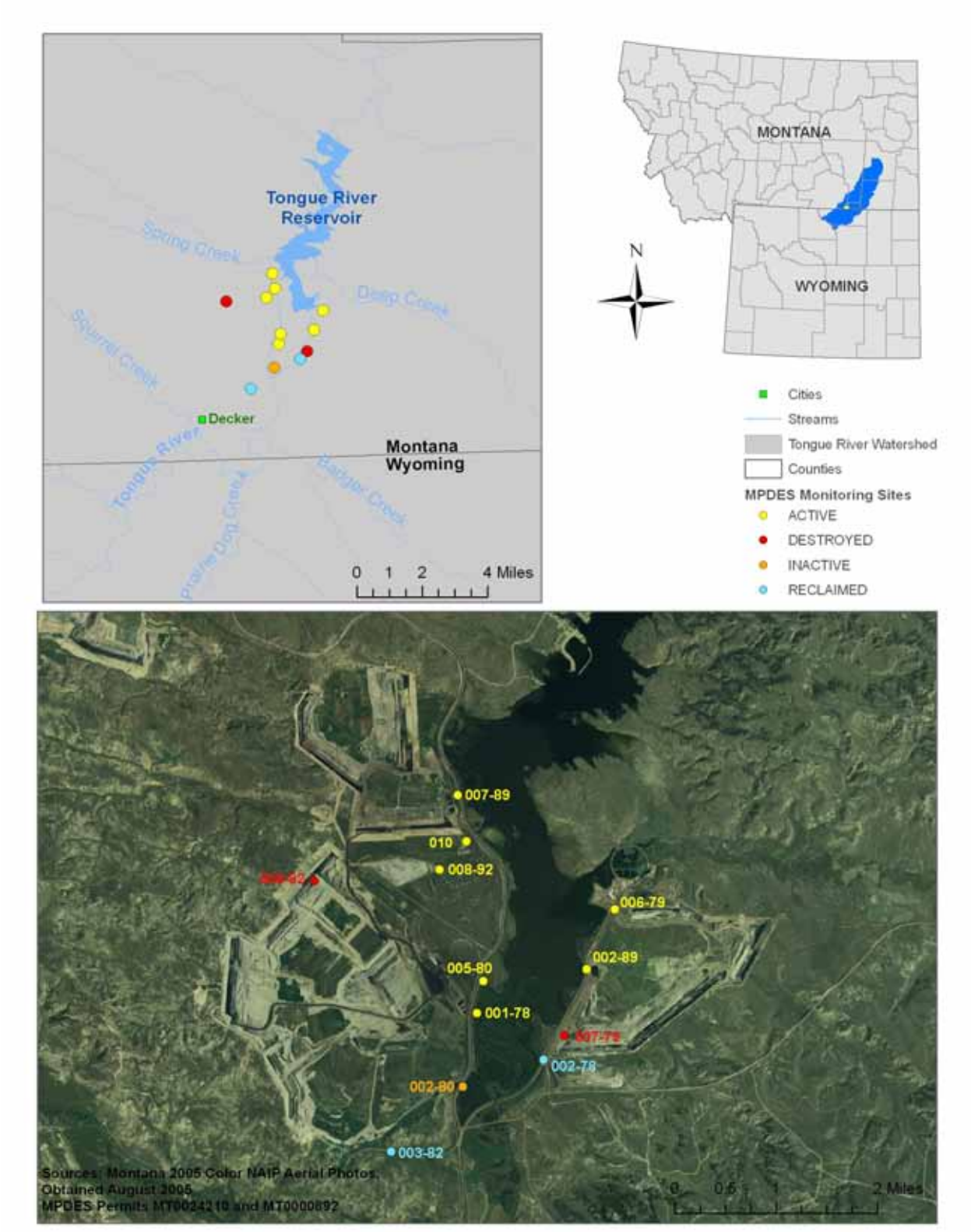

Figure A-1. Location of the Decker Coal Mines and MPDES monitoring locations (MPDES Permit # MT0000892 and MT0024210).

Permit parameters and limits vary per outfall. Table A-1 summarizes the permitted parameters for outfalls at both mine sites. Both the East and West Decker Mine MPDES discharge permits were renewed by Montana DEQ on September 28, 2006.

Table A-1. Permit limits for the Decker East and West Coal Mines (Limits as of September 28, 2006.)

Mine	Outfall	Parameter	Units	Daily Max	30-Day Average
West	001-78, 005-80, and 007-89	TSS	mg/L	70	35
		Iron (Total Recoverable)	mg/L	7.0	3.5
		SAR	NA	16.3	14
		EC	µS/cm	3,488	3,000
		Selenium	mg/L	0.013	0.01
		Lead (Total Recoverable)	mg/L	0.295	0.273
		Copper (Total Recoverable)	mg/L	0.041	0.032
	008-92 and 010 (non precipitation driven)	TSS	mg/L	70	35
	008-92 (non precipitation driven)	Iron (Total Recoverable)	mg/L	7.0	3.5
	010 (non precipitation driven)	Iron (Total Recoverable)	mg/L	7.0	3.0
	008-92, 010 (precipitation driven)	Total Setteable Solids	mg/L	0.5	NA
		pH	NA	Range 6.0-9.0	Range 6.0-9.0
East	002-89	TSS	mg/L	35	70
		Iron (Total Recoverable)	mg/L	7.0	3.5
		SAR	NA	17.8	20.6
		Dissolved Aluminum	mg/L	0.5	0.7

Outfall monitoring data from the facility's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). Samples were obtained at the outflow from the settling ponds. Additional data were also available from Montana DEQ's Industrial and Energy Minerals Bureau (IEMB) as part of compliance monitoring for the Strip and Underground Mine Reclamation Act. Data for the permitted outfalls are summarized in Table A-2.

Table A-2. Summary of the West Decker and East Decker outfall data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Decker West Coal Mine (MT0000892)	001-78	Jun 1979-Jan 2001	19%	1.26	1,811[3]	1,402	16.6[3]	NA	0.074[3]	0.80[3]
	002-80	Jul 1980-Dec 1994	NA	NA	2,424[3]	1,578[3]	17.2[3]	NA	0.027[3]	0.65[3]
	005-80	Jan 1998-Present	0%	0.00[2]	NA	578[3]	10.5[3]	NA	0.255[3]	0.143[3]
	007-89	Mar 1990-Present	100%	2.25	2,624[3]	2,161	5.3[3]	NA	0.047[3]	0.52[3]
	008-92	Jan 1998-Present	NA	0.00[2]	NA	NA	NA	NA	NA	NA
	010	Dec 2004-Present	NA	0.00[2]	NA	NA	NA	NA	NA	NA
Decker East Coal Mine (MT0024210)	002-78 002-89[4]	Sep 1978-Present	99%	1.39	2,843[3]	2,027	14.8[3]	NA	0.038[3]	1.276[3]
	006-79	Feb 1980-Sep 2001	NA	NA	3,565[3]	2,502[3]	12.8[3]	NA	0.024[3]	0.446[3]
	007-79	Apr 1980-Dec 1990	NA	NA	2,449[3]	1,446[3]	10.6[3]	NA	0.023[3]	0.271[3]

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
[2]No discharges reported in the PCS database.
[3]IEMB data. No PCS data available.
[4]The outfall was reclaimed in 1989, and a new location was assigned as outfall #002-89 (see Figure A-1)
NA – not available

A.2.1.2 Spring Creek Coal Mine (MT0024619 and MTR300198)

The Spring Creek Coal Mine is located approximately 7.0 miles northwest of the Town of Decker, Montana and 6.0 miles west of the Tongue River Reservoir in Big Horn County, Montana. Open pit mine operations began in the early 1980, with the first shipment of coal occurring in 1982 (DOI, 1979). The Spring Creek mine is currently permitted by Montana DEQ (MPDES Permit # MT0024619) to discharge mine water to unnamed tributaries to Spring Creek, which discharges to the Tongue River Reservoir (MDEQ, 1996). The current MPDES permit expired on September 30, 2002.

Spring Creek Coal Mine currently has 7 permitted outfalls – 001, 002, 007, 009, 010, 011, and 012 (see Figure A-2). The permit states that all discharges are to unnamed tributaries to Spring Creek, although at least one settling pond is evident from the 2005 aerial photos (at outfall #002). It also appears that at least one of the outfalls (#011) has been mined. Table A-3 summarizes the permit limits for the outfalls.

Table A-3. Permit limits for the Spring Creek Coal Mine (Limits as of September 30, 2002.)

Parameter	Units	Daily Max	30-Day Average
Iron, total	mg/L	7.0	3.5
Oil and Grease	mg/L	15	10
Total Suspended Solids	mg/L	70	35

Outfall monitoring data from Spring Creek's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 20, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). Data for permitted outfalls are summarized below:

- **All Discharge Points (i.e., sum of all outfalls) –** Monthly monitoring data were available from January 1998 through July 2006, and consisted of 103 reported events (i.e., monthly reporting values). Spring Creek is currently not required to report flows rates or water quality concentrations, just the presence or absence of flow. Of the 103 reported events, 99 events had "no discharge" (96 percent), and two months had no reported values (May 2003 and June 2004). May and June of 2005 were the only two months with reported flows. No information was available for individual outfalls.

The Spring Creek Coal mine also has a permitted stormwater discharge (MPDES Permit # MTR300198). The permit was issued by Montana DEQ on February 6, 2003, and expires on November 16, 2007. Stormwater is discharged through one outfall (#001) into an unnamed tributary to Spring Creek. Outfall monitoring data from Spring Creek's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 20, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). Data for the permitted outfall are summarized below:

- **Outfall 001 –**Bi-yearly monitoring data were available from June 2003 through June 2006, and consisted of 7 reported events (i.e., bi-yearly reporting values). Of the 7 reported events, 6 events had "no discharge" (86 percent), and one months had no reported values (June 2003).

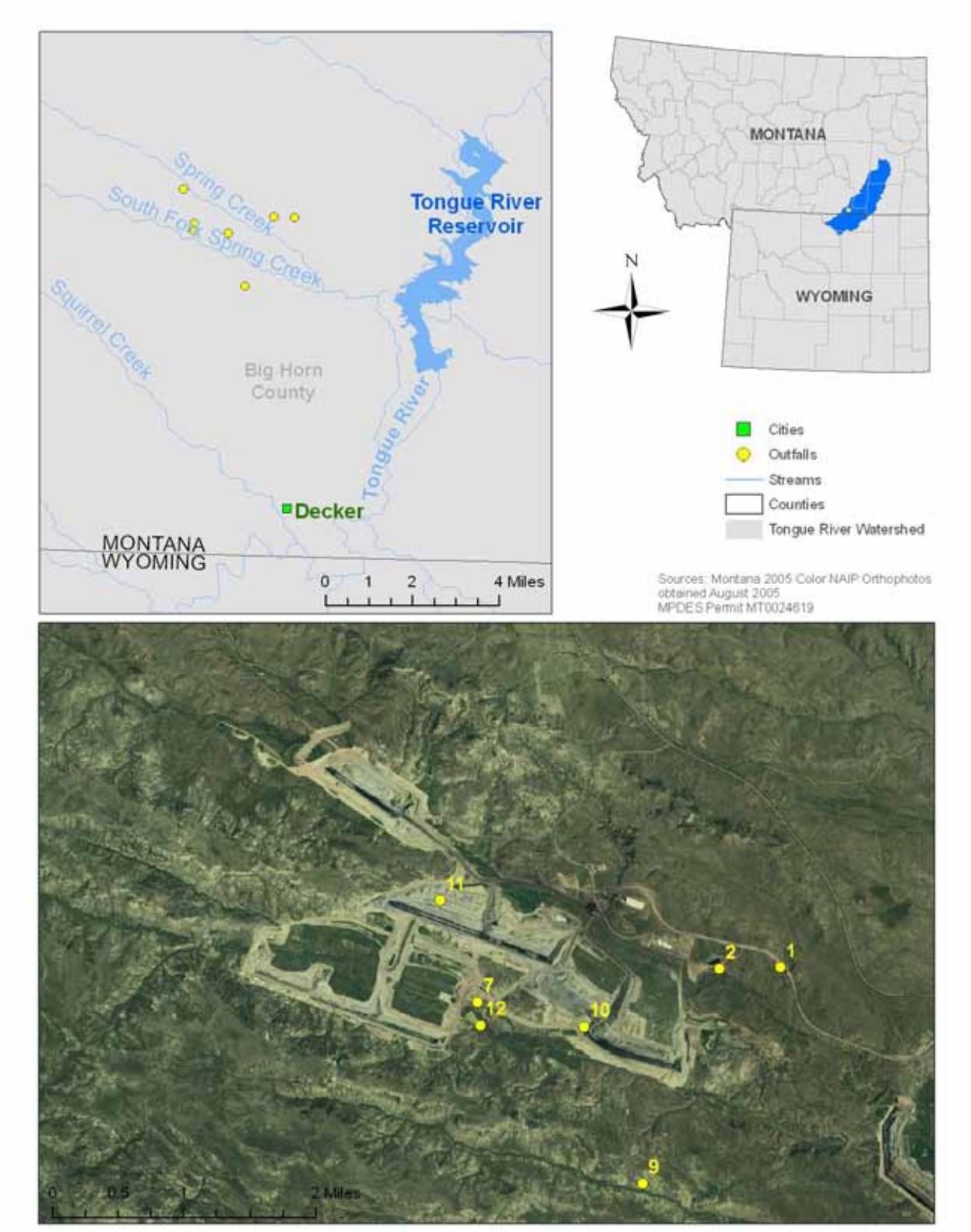

Figure A-2. Location of the Spring Creek Coal Mine and permitted outfalls (MPDES Permit # MT0024619 and MTR300198).

A.2.2 Coal Bed Methane

Two facilities in Montana currently have permits to discharge coal bed methane (CBM) produced water in the Tongue River watershed – Fidelity Exploration and Production Company (Fidelity) and Pinnacle Gas Resources (Pinnacle). Both facilities discharge directly to the Tongue River. Fidelity also has a separate permit to treat and discharge CBM produced water into the Tongue River. No other facilities in Montana are currently permitted for CBM discharges. The following sections describe the facilities in more detail.

A.2.2.1 Pinnacle Gas Resources – Coal Creek CBM Field (MT0030660)

Pinnacle Gas Resources (formerly Powder River Gas, LLC) Coal Creek Coal Bed Methane (CBM) operation is located approximately 10.5 miles northeast of the City of Decker, Montana, and approximately 1.1 mile northeast of the Tongue River Reservoir Dam in the Tongue River watershed, Montana (Figure A-3). Montana DEQ granted an MPDES permit (#MT0030660) to Pinnacle on November 19, 2004 to discharge coal bed methane waste water to the Tongue River, and drilling operations for a pilot project began in January of 2005 (MDEQ, 2004). According to the EIS, the initial Pilot Project would result in 16 test wells, with an additional 48 wells proposed for future drilling (MBOGC, 2005a). The Pilot Project covered approximately 760 acres, and future drilling would add another 3,640 acres to the facility (see Figure A-3). As of August 19, 2005, 10 of the pilot wells were completed, and the Montana Board of Oil and Gas Conservation (MBOGC) concluded that Pinnacle could proceed with the remaining 48 wells (MBOGC, 2005b). As of October 18, 2006, it is unclear how many additional wells have been drilled.

Pinnacle is permitted to discharge water at one outfall (#001), which flows directly into the Tongue River approximately one mile downstream of the Tongue River Reservoir Dam (see Figure A-3). Permitted pollutants include total suspended solids (TSS), cadmium, selenium, specific conductance, and sodium adsorption ratio (SAR). There is no permit limit for flow. Table A-4 summarizes the permit limits. To meet the specific conductance and SAR limits, Pinnacle uses a Higgins Loop Counter Current Ion Exchange to treat produced water, which is then blended with untreated water and discharged to the Tongue River (WPCAC, 2005).

Table A-4. Permit limits for the Pinnacle Gas Resources Coal Creek CBM Field.

Pollutant	Season	Daily Maximum Limit	Monthly average Limit
TSS (mg/L)	January 1-December 31	30	25
Cadmium (µg/L)	January 1-December 31	0.48	0.054
Selenium (µg/L)	January 1-December 31	3.0	0.75
Specific Conductance	March 1-October 31	1,500	1,000
	November 1-February 28	2,500	1,500
SAR	March 1-October 31	4.5	3.0
	November 1-February 28	7.5	5.0

Outfall monitoring data from Pinnacle's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). Data for permitted outfalls are summarized in Table A-5.

Table A-5. Summary of the Pinnacle CBM effluent (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Pinnacle Coal Creek CBM Field (MT0030660)	001	Apr 2005-Present	100%	0.50	227	159	2.73	0.47	0.16	0.08

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.

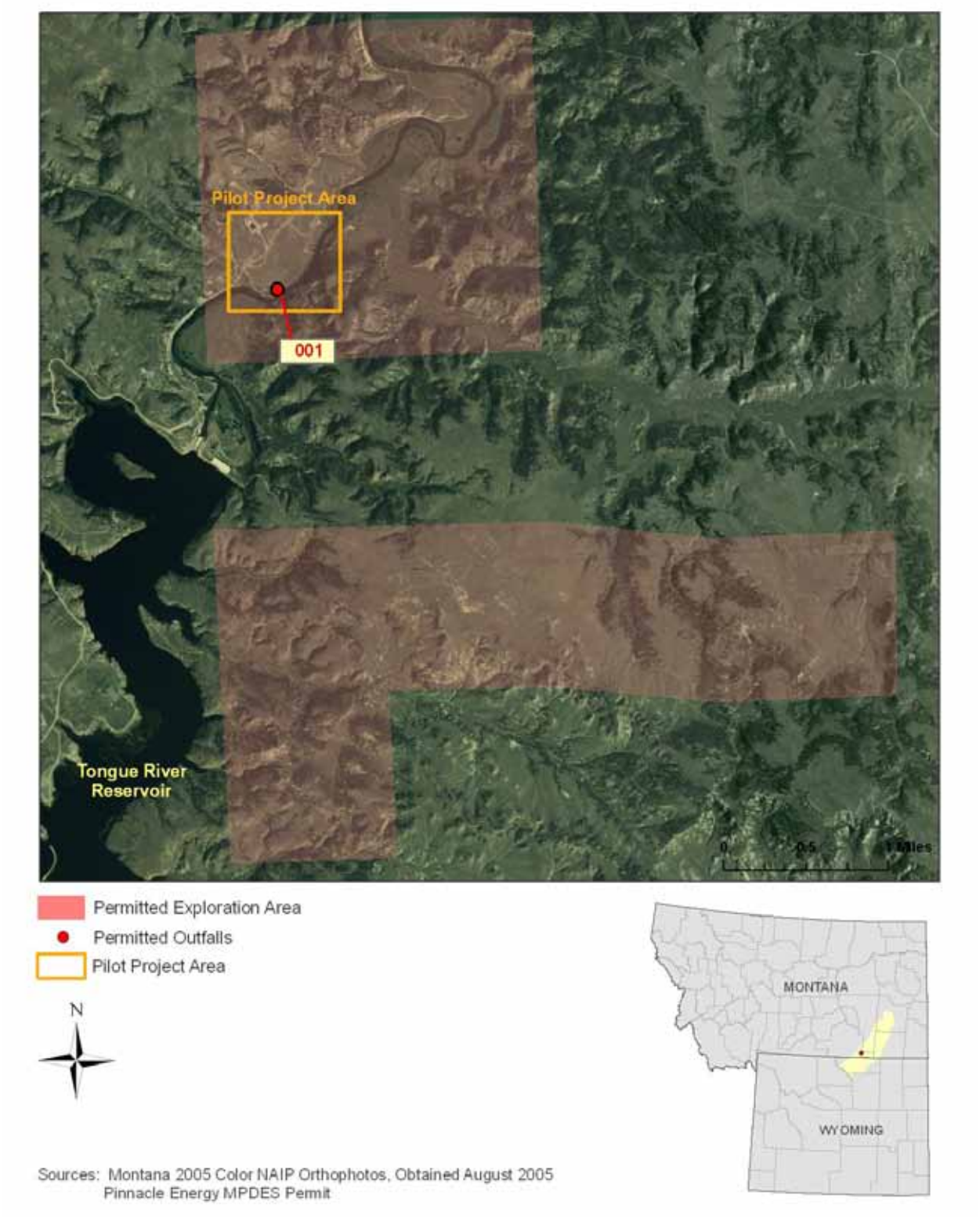

Figure A-3. Location of the Pinnacle Energy CBM Field and permitted outfalls (Permit # MT0030660).

A.2.2.2 Fidelity Exploration and Production Company – Tongue River Project (MT0030457)

Fidelity Exploration and Production Company (Fidelity) Tongue River Coal Bed Methane (CBM) Project is located near the Town of Decker, Montana along the Tongue River at the Montana-Wyoming State Line (Figure A-4). Fidelity (originally Redstone Gas Partners, LLC) began drilling in the Tongue River watershed on March 31, 1997 (MBOGC, 2006). Between March 31, 1997 and June 16, 2000, Fidelity discharged CBM water to the Tongue River and Squirrel Creek without an MPDES permit because of Montana Code Annotated (MCA) 75-5-401, which states that unaltered groundwater discharges are exempt from the MPDES permitting process. Montana DEQ issued Fidelity a MPDES discharge permit on June 16, 2000, which was revised on July 3, 2000. The permit allowed for direct discharge to the Tongue River via 12 outfalls, with an option to add additional outfalls as necessary (MDEQ, 2000). A second permit application to discharge water to Squirrel Creek (tributary to the Tongue River) was denied on June 16, 2000 because the discharge would not meet the State's non-degradation requirement for fluoride and ammonia (Simonich, 2000). Fidelity was ordered to discontinue direct discharges to Squirrel Creek, and after June 2000, discharges in the Squirrel Creek watershed were diverted to holding ponds (Williams, 2000).

The Fidelity MPDES permit (#MT0030457) was renewed by Montana DEQ on February 3, 2006, and became effective on April 1, 2006. According to the permit, there are currently 16 outfalls that directly discharge to the Tongue River (see Figure A-4 for outfalls locations). CBM discharge is also routed to several storage ponds located throughout the project area. However, the MPDES program does not regulate these outfalls or ponds. Permit parameters and limits for the direct discharges are summarized in Table A-6. The current permit also provides flow limits based on the season and in-stream flow of the Tongue River (MDEQ, 2006e):

- Between November 1 and February 28, the total flows discharged from Outfall 001- 014 and Outfall 016 shall not exceed 2,500 gallons per minute (gpm).
- Between March 1 and June 30, the total flows discharged from Outfall 001- 014 and Outfall 016 shall not exceed 2,375 gallons per minute (gpm).
- When daily stream flow values are less than 35 cubic feet per second (cfs) as recorded at USGS gauging station 06306300 (Tongue River at State Line near Decker), the permittee shall conduct daily instream monitoring of specific conductance at location DWS-A. The permittee shall cease discharging to the Tongue River if the measured instream specific conductance exceeds the following values on any on two consecutive calendar days:

    - November 1 through March 1: ***2,500 µS/cm***
    - March 2 through October 31: ***1,500 µS/cm***

    In the event the permittee ceases discharge due to these conditions, discharges cannot recommence until the flow in the Tongue River at the gauge identified above exceeds 35 cfs.

Table A-6. Permit limits for the Fidelity Tongue River Project CBM outfalls (Limits as of April 1, 2006.)

Outfalls	Parameter	Units	Daily Max	30-Day Average
001 through 014, and 016	TSS	mg/L	30	25
	pH	–	6.5-9	
	Oil/Grease	mg/L	10	NA
	Specific Conductance	µS/cm	Variable	Variable

Source: MDEQ, 2006e.

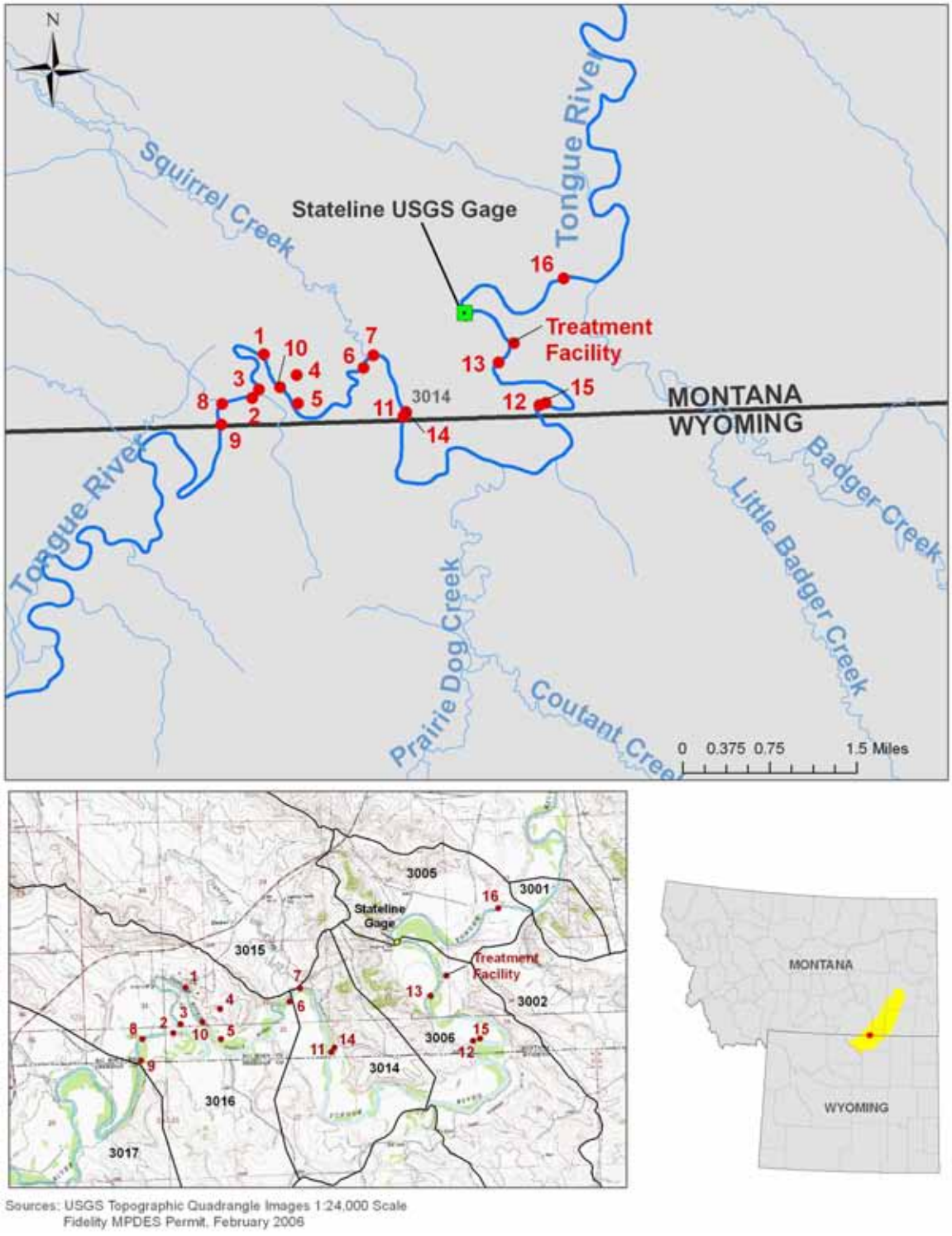

Figure A-4. Location of Fidelity Exploration and Production Company's Tongue River Project and permitted outfalls (Permit # MT0030457).

Outfall monitoring data were obtained from Montana DEQ as an electronic data file on December 8, 2006. The text file contained outfall and Tongue River monitoring data collected between June 2000 and October 2005. Data were reported as average values per month. It is assumed that outfalls discharging in October 2005 are still presently operational. Table A-7 summarizes the period of record and water quality data for each outfall.

Table A-7. Summary of the Fidelity direct discharges.

Outfall	Period of Operation	Months with Flow[2]	Average Flow (cfs)	Average SC (µS/cm)	Average SAR	Average Ammonia (mg/L)	Average TN (mg/L)	Average TP (mg/L)
001	Apr 1997 – Present[1]	100%	0.07	1,953	53.8	1.79	0.76	0.17
002	Jan 2002 – Present	100%	0.02	1,671	52.6	1.71	1.33	0.09
003	Apr 1997 – Jan 2003[1]	100%	0.02	1,866	47.7	1.82	NA	NA
004	Apr 1997 – Present[1]	100%	0.50	1,984	51.0	1.83	1.60	0.10
005	Apr 1997 – Present[1]	100%	0.02	1,856	52.9	1.73	1.27	0.07
006	Apr 1997 – Present[1]	100%	0.43	1,910	55.5	1.63	1.25	0.08
007	Apr 1997 – Present[1]	100%	0.15	1,964	50.5	1.77	1.57	0.08
008	Apr 1997 – Present[1]	100%	0.13	2,174	52.2	2.45	1.37	0.10
009	Apr 1997 – Present[1]	100%	0.15	1,818	52.2	1.70	NA	NA
010	Jun 2003 – Present	100%	0.01	2,058	50.2	1.64	1.30	0.06
011	Apr 1997 – Aug 2000[1]	100%	0.01	NA	45.0	2.24	NA	NA
012	Aug 2001 – Present	100%	0.23	2,091	54.8	2.01	1.60	0.07
013	Aug 2001 – Present	100%	0.09	2,092	55.7	1.95	1.61	0.09
014	Mar 2003 – Present	100%	0.04	1,899	53.5	1.81	1.43	0.08
015	Mar 2003 – Present	100%	0.69	2,449	61.5	2.28	1.99	0.10
016	Dec 2003 – Present	100%	0.24	2,009	52.2	1.89	0.76	0.17

[1]It is assumed that this outfall was operational from April 1997 to June 2000, although no data are available for this time period because Fidelity was not required to have an MPDES permit or to monitor CBM discharges.
[2]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.

As shown in Figure A-4, the original Fidelity project area was limited to the CX field, with discharges occurring to Squirrel Creek and the Tongue River. Since 2003, Fidelity has requested five different expansions to the original project area including the Deer Creek, Pond Creek, Dry Creek, Badger Creek, and Coal Creek expansions. The environmental assessments for each of these expansions are located online at http://bogc.dnrc.state.mt.us/CoalBedMeth.asp. As of October 25, 2006, BLM and the Montana Bureau of Oil and Gas (MBOG) have approved each of these expansions. According to MBOG, Fidelity has drilled 916 wells in the Tongue River Project Area between March 31, 1997 and December 8, 2006 (MBOG, 2006).

A.2.2.3 Fidelity Tongue River Project Treatment Facility (MT0030724)

The Fidelity Tongue River Water Treatment Facility is located approximately 2.5 miles southeast of the Town of Decker in Big Horn County, Montana. Montana DEQ granted an MPDES permit (#MT0030724) to Fidelity Exploration and Production Company (Fidelity) on February 3, 2006 to treat and discharge CBM water to the Tongue River (MDEQ, 2006f). The treatment facility receives water from Fidelity's CBM wells located in the Badger Creek and Coal Creek Project Areas (see Figure A-5). Water is then treated and blended with untreated water before being discharged to the Tongue River.

Fidelity is permitted to discharge water at one outfall (#001), which flows directly into the Tongue River approximately 0.65 miles north of the Montana-Wyoming border (see Figure A-5). Permitted pollutants include total suspended solids (TSS), total nitrogen, SAR, specific conductance, and heat load. Table A-8 summarizes the permit limits.

Table A-8. Permit limits for the Fidelity Treatment Facility.

Pollutant	Season	Daily Maximum Limit	Monthly Average Limit
TSS (mg/L)	Jan 1-Dec 31	30	25
Total Nitrogen (mg/L)	Nov 1-Mar 1	1.7	1.2
	Mar 2-Jun 30	1.8	1.3
	Jul 1-Oct 31	1.6	1.1
SAR	Nov 1-Mar 1	7.5	2.0
	Mar 2-Oct 31	4.5	3.0
Specific Conductance (µS/cm)	Nov 1-Mar 1	2,500	1,500
	Mar 2-Oct 31	1,500	1,000
Heat Load (BTU/day)	Nov 1-Mar 1	1.14×10^9	NA
Flow	Jan 1-Dec 31	1,700 GPM (3.79 cfs)	NA
pH	Jan 1-Dec 31	6.5-9.0	
Oil and Grease	Jan 1-Dec 31	10.0 mg/L	NA

Source: MDEQ, 2006f

Outfall monitoring data from Fidelity's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 25, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). Data for the permitted outfall are summarized in Table A-9

Table A-9. Summary of effluent data from the Fidelity treatment facility (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Fidelity CBM Treatment Facility (MT0030724)	001	Jun 2006-Present	33%	0.780	870	590	7.2	0.50	0.08	0.30

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.

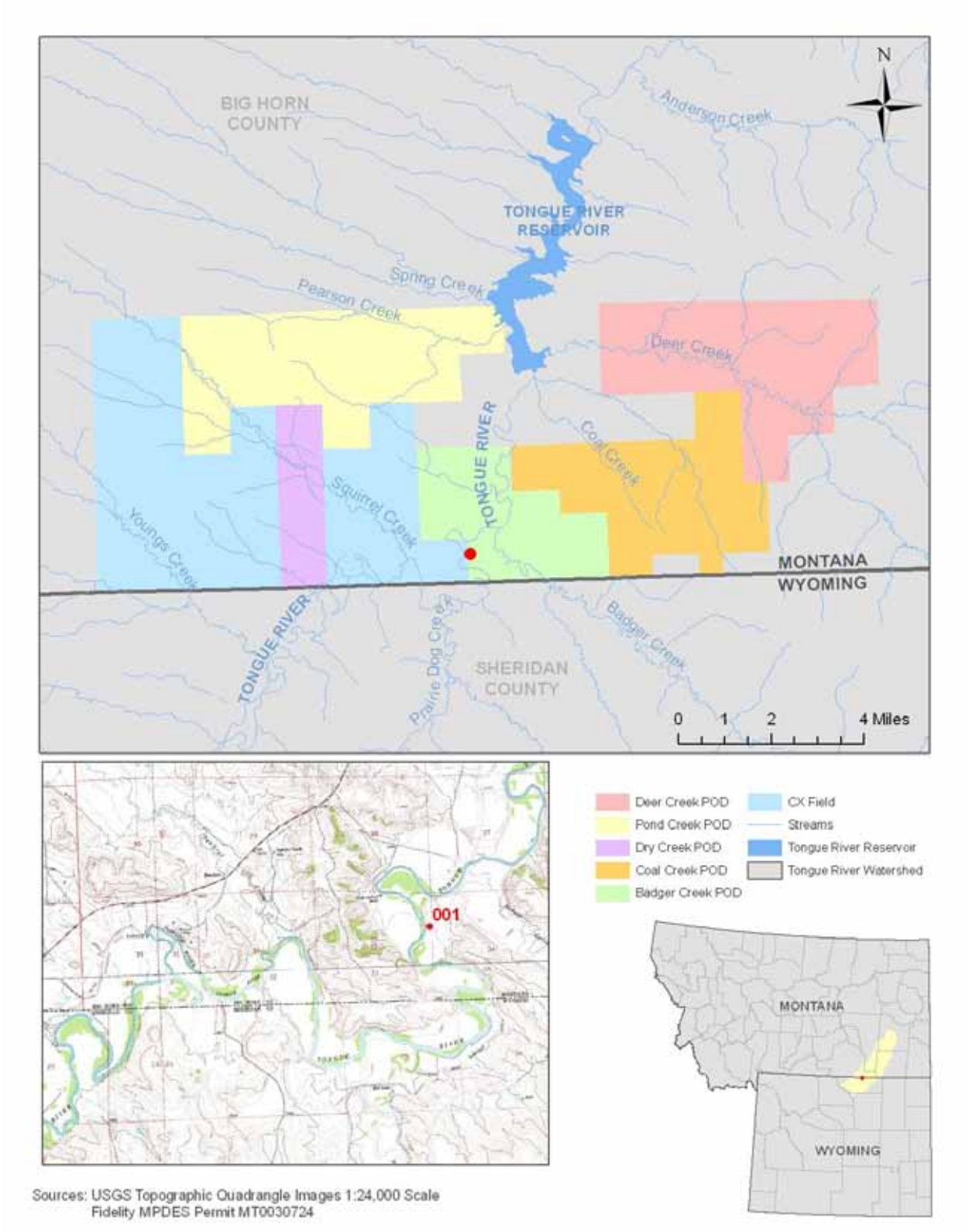

Figure A-5. Location of the Fidelity Tongue River Treatment Facility outfall (Permit # MT0030724).

A.2.3 Wastewater Treatment

At the time of this report, two wastewater treatment facilities are operational within the Tongue River watershed in Montana – City of Ashland Lagoons and City of Birney Lagoons. The following sections describe the facility locations, permit limits, outfalls, and effluent monitoring data.

A.2.3.1 City of Ashland Lagoon

The City of Ashland Wastewater Treatment Lagoon is located just north of the City of Ashland, Montana. The lagoon does not discharge to any surface waterbodies and is lined with a membrane to reduce infiltration. Therefore no MPDES is issued for its operation (Personal Communications, David Rise, USEPA, March 21, 2007). Wastewater is land applied to 12 acres of alfalfa.

A.2.3.2 City of Birney Lagoon

The City of Birney Wastewater Treatment Lagoon is located just downstream of the City of Birney, Montana. The lagoon does not discharge to any surface waterbodies and is lined with a membrane to reduce infiltration. USEPA personal also indicated that the lagoon is significantly oversized for the community it serves, thereby almost eliminating the chance of overflows (Personal Communications, Julie Orr, USEPA, April 2, 2007). Because it does not discharge to a surface waterbody, and there is little expectation for an overflow, no MPDES permit was issued for its operation (Personal Communications, David Rise, USEPA, March 21, 2007). Because no surface water discharge occurs, no monitoring data are available.

A.2.4 Montana Permits – Summary

Currently, ten facilities with a total of 31 outfalls have MPDES permits for surface water discharges in the Tongue River watershed, Montana (Table A-10). Permits are primarily for coal mining and CBM development. Coal mining and mine discharges began in the early 1970s and continue to occur today at the East Decker, West Decker, and Spring Creek coal mines. Fidelity began coal bed methane development in 1997, which has continued at an increasing rate to the present time. Most recently, Montana DEQ granted additional permits to Fidelity and Pinnacle to treat and discharge CBM wastewater.

Table A-10. Summary of coal mine and CBM direct discharge data in the Tongue River, Montana (average values are reported).

Facility	Outfall	Period of Operation	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Fidelity Tongue River CBM Project (MT0030457)	001	Apr 1997-Present	0.066	1,953	1,264	53.76	0.76	0.17	1.79
	002	Jan 2002-Present	0.023	1,671	1,039	52.59	1.33	0.09	1.71
	003	Apr 1997-Jan 2003	0.022	1,866	1,215	47.65	NA	NA	1.82
	004	Apr 1997-Present	0.497	1,984	1,275	51.04	1.60	0.10	1.83
	005	Apr 1997-Present	0.022	1,856	1,190	52.87	1.27	0.07	1.73
	006	Apr 1997-Present	0.429	1,910	1,222	55.52	1.25	0.08	1.63
	007	Apr 1997-Present	0.145	1,964	1,267	50.53	1.57	0.08	1.77
	008	Apr 1997-Present	0.125	2,174	1,392	52.24	1.37	0.10	2.45
	009	Apr 1997-Present	0.149	1,818	1,161	52.23	NA	NA	1.70
	010	Jun 2003-Present	0.005	2,058	1,294	60.24	1.30	0.06	1.64
	011	Jun 2000-Aug 2000	0.003	2,070	1,360	45.00	NA	NA	2.24
	012	Aug 2001-Present	0.233	2,091	1,327	54.83	1.60	0.07	2.01
	013	Aug 2001-Present	0.091	2,092	1,326	55.72	1.61	0.09	1.95
	014	Mar 2003-Present	0.044	1,899	1,176	53.46	1.43	0.08	1.81
	015	Mar 2003-Present	0.692	2,449	1,548	61.46	1.99	0.10	2.28
	016	Dec 2003-Present	0.239	2,009	1,278	52.19	0.76	0.17	1.89
Fidelity CBM Treatment Facility (MT0030724)	001	Jun 2006-Present	0.780	870	590	7.2	0.50	0.08	0.30
Pinnacle Coal Creek CBM Field (MT0030660)	001	Apr 2005-Present	0.499	227	159	2.73	0.47	0.16	0.08
Decker West Coal Mine (MT0000892)	001	Jun 1979-Jan 2001	1.26	1,811[b]	1,402	16.58[b]	NA	0.074[b]	0.80[b]
	002	Jul 1980-Dec 1994	NA	2,424[b]	1,578[b]	17.19[b]	NA	0.027[b]	0.65[b]
	005	Jan 1998-Present	0.00[a]	NA	578[b]	10.51[b]	NA	0.255[b]	0.143[b]
	007	Mar 1990-Present	2.25	2,624[b]	2,161	5.29[b]	NA	0.047[b]	0.52[b]
	008	Jan 1998-Present	0.00[a]	NA	NA	NA	NA	NA	NA
	010	Dec 2004-Present	0.00[a]	NA	NA	NA	NA	NA	NA
Decker East Coal Mine (MT0024210)	002	Sep 1978-Present	1.39	2,843[b]	2,027	14.80[b]	NA	0.038[b]	1.276[b]
	006	Feb 1980-Sep 2001	NA	3,565[b]	2,502[b]	12.84[b]	NA	0.024[b]	0.446[b]
	007	Apr 1980-Dec 1990	NA	2,449[b]	1,446[b]	10.55[b]	NA	0.023[b]	0.271[b]
Spring Creek Coal Mine (MT0024619)	All	January 1998-Present	NA	NA	NA	NA	NA	NA	NA

[a1]No discharges reported in the PCS database.
[b]IEMB data. No PCS data available.
NA – Not Available

A.3 Wyoming Permits

Over 350 NPDES permits have been issued to facilities in the Tongue River watershed in Wyoming. Some of these are for temporary discharges or stormwater permits, while others are for continuous discharges to surface waterbodies. The following sections summarize the permits and their available data.

A.3.1 Coal Bed Methane

Coal bed methane production in the Tongue River watershed in Wyoming began in 1999. As of February 2007, 13 companies have drilled 6,897 wells for CBM production or groundwater monitoring (WOGCC, 2007). The WOGC reports that 2,688 of those wells are producing coalbed methane, and the remaining wells are plugged, abandoned, have expired permits, or are for monitoring purposes.

CBM outfalls and their effluent are regulated by Wyoming DEQ. The online Wyoming DEQ CBM database (available at deq.state.wy.us/wqd/WYPDES_Permitting/WYPDES_cbm/cbm.asp) reports that 359 permits have been issued for CBM facilities in the Tongue River watershed (WDEQ, 2007). Of those, 171 are for temporary or permanent surface water discharges (Personal Communications, Kathy Shreve, Wyoming DEQ, December 14, 2006). The remaining permits (188) are for stormwater discharges. The remainder of this section focuses only on the permanent surface water discharges.

Wyoming DEQ provided a Microsoft Access database (dated January 23, 2007) of data for CBM facilities in the Tongue River watershed, Wyoming. The database contained over one million records of CBM DMR data dating from March 1, 1999 to January 1, 2007. Wyoming DEQ personnel indicated that the database contains information for all of the permitted CBM facilities in the Tongue River watershed through January 1, 2007 (Personal Communications, Wyoming DEQ, March 19, 2007). The database contained data for 420 CBM outfalls that discharge to ponds and 7 outfalls that discharge directly to streams. Their locations are shown in Figure A-6). An estimated 222 of the outfalls discharge to off-channel ponds, and 198 discharges to on-channel ponds (WDEQ, 2007) Of the 427 outfalls, only 410 had reported flows. The other 17 outfalls either had no reported data or had reported discharges of zero. Wyoming personnel indicated that this was common, as outfalls are often permitted and built but not used (Personal Communications, Wyoming DEQ, March 19, 2007).

Because of the large number of outfalls, the raw data are not included in this report (a database is available upon request). The total flow from the outfalls over time, as reported by Wyoming DEQ and the Wyoming Oil and Gas commission, is shown in Figure A-7. Discharges from CBM wells in Wyoming began in March 1999 with an average total flow of 0.5 cubic feet per second. Flows then significantly increased between 2002 and 2006, where total flows ranged from 5 to 13 cubic feet per second. The average reported salinity and SAR for all of the outfalls was 1,900 µS/cm and 38.1, respectively. No nutrient data were available for the Wyoming CBM outfalls.

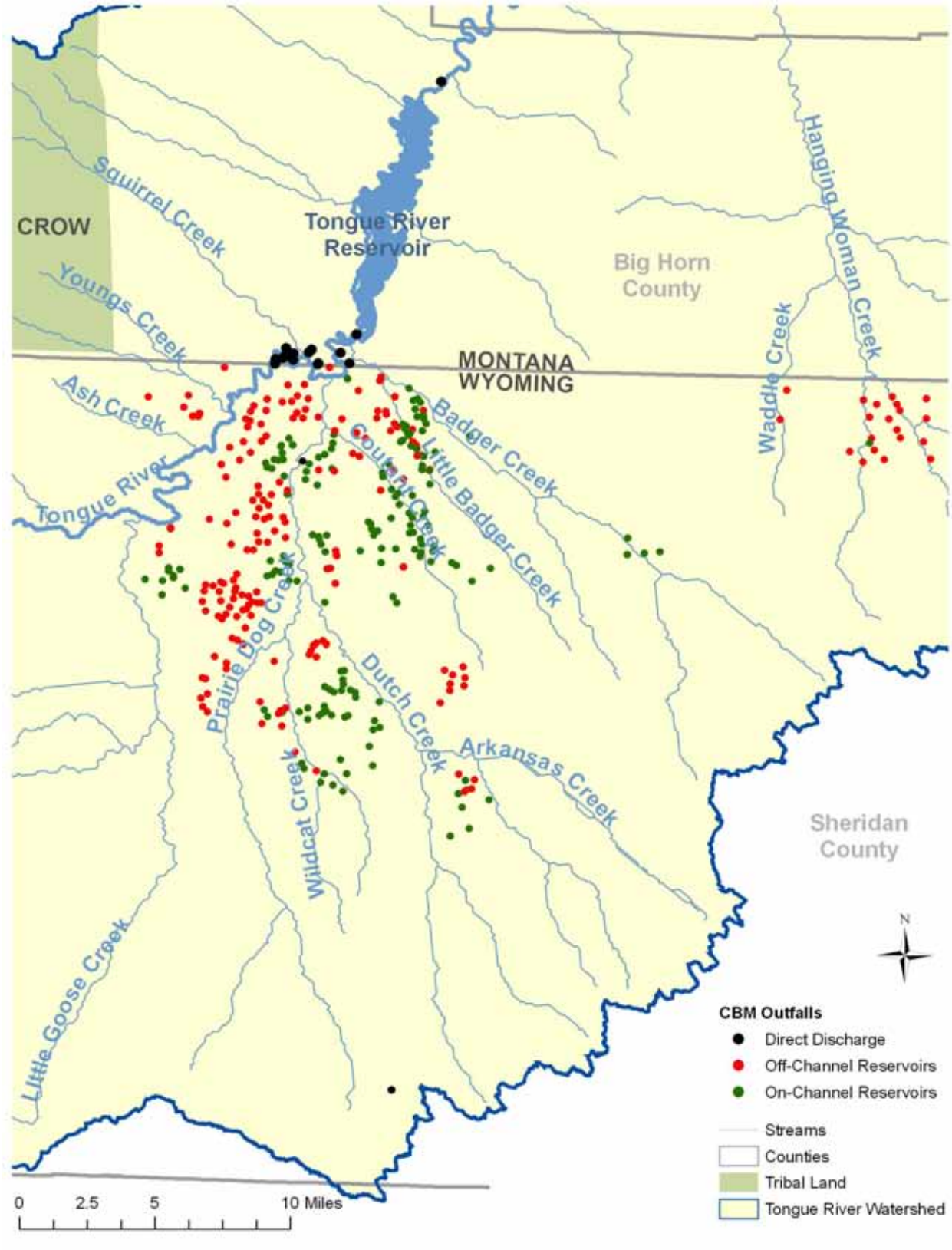

Figure A-6. Location of the CBM outfalls.

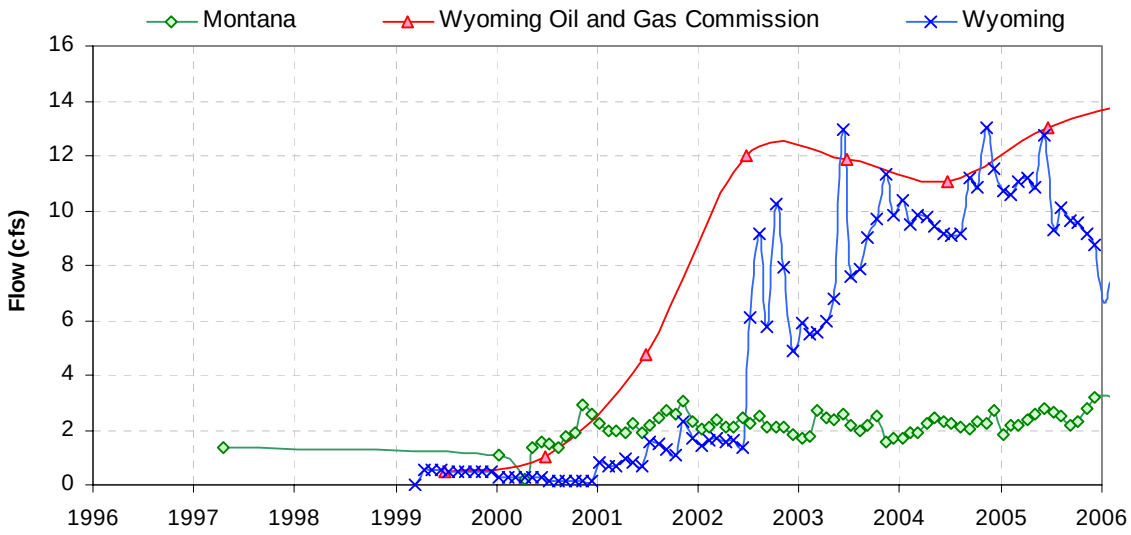

Figure A-7. Summary of total monthly CBM flows in Montana and Wyoming, 1997-2006.

A.3.2 Wastewater Treatment

At the time of this report, six wastewater treatment facilities are operational within the Tongue River watershed in Wyoming – City of Sheridan Wastewater Treatment Plant (WWTP), City of Dayton Lagoons, City of Ranchester Lagoons, Burgess Junction Dump Station lagoon, Powder Horn Ranch community system, and the Big Horn Mountain KOA treatment system. The following sections describe the facility locations, permit limits, outfalls, and effluent monitoring data.

A.3.2.1 City of Sheridan WWTP (WY0020010)

The City of Sheridan Wastewater Treatment Plant (WWTP) is located just downstream of the City of Sheridan, Wyoming (Figure A-8). No information was available regarding the plant's construction date; however, records indicate that it has been in operation at least since May 15, 1978 (USEPA, 2007). The WWTP currently operates under NPDES permit WY0020010, which allows for one primary discharge point into Goose Creek just downstream of the City of Sheridan. Two overflow discharge points are also authorized by this permit (WDEQ, 2005a). Figure A-8 shows the location of the outfalls.

The treatment plant utilizes an activated sludge process with extended aeration, and has a permitted flow of 4.4 MGD (6.8 cfs) (City of Sheridan, 2006) (WDEQ, 2005a). All permit limits for the facility are shown in Table A-11.

Table A-11. Permit limits for the Sheridan WWTP (Limits as of June 2, 2005.)

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms	#/100 mL	400	200
Total Suspended Solids	mg/L	90	30
Ammonia, Total as N (May-September)	mg/L	3.56	1.78
Ammonia, Total as N (October-April)	mg/L	19.02	9.51
Total Residual Chlorine	mg/L	0.02	NA
Flow	MGD	NA	4.4

Outfall monitoring data from the WWTP's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-12.

Table A-12.Summary of the Sheridan WWTP effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)
Sheridan WWTP (WY0020010)	001	1988 – Present	100%	4.6	838	442	2.73	NA	3.7

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

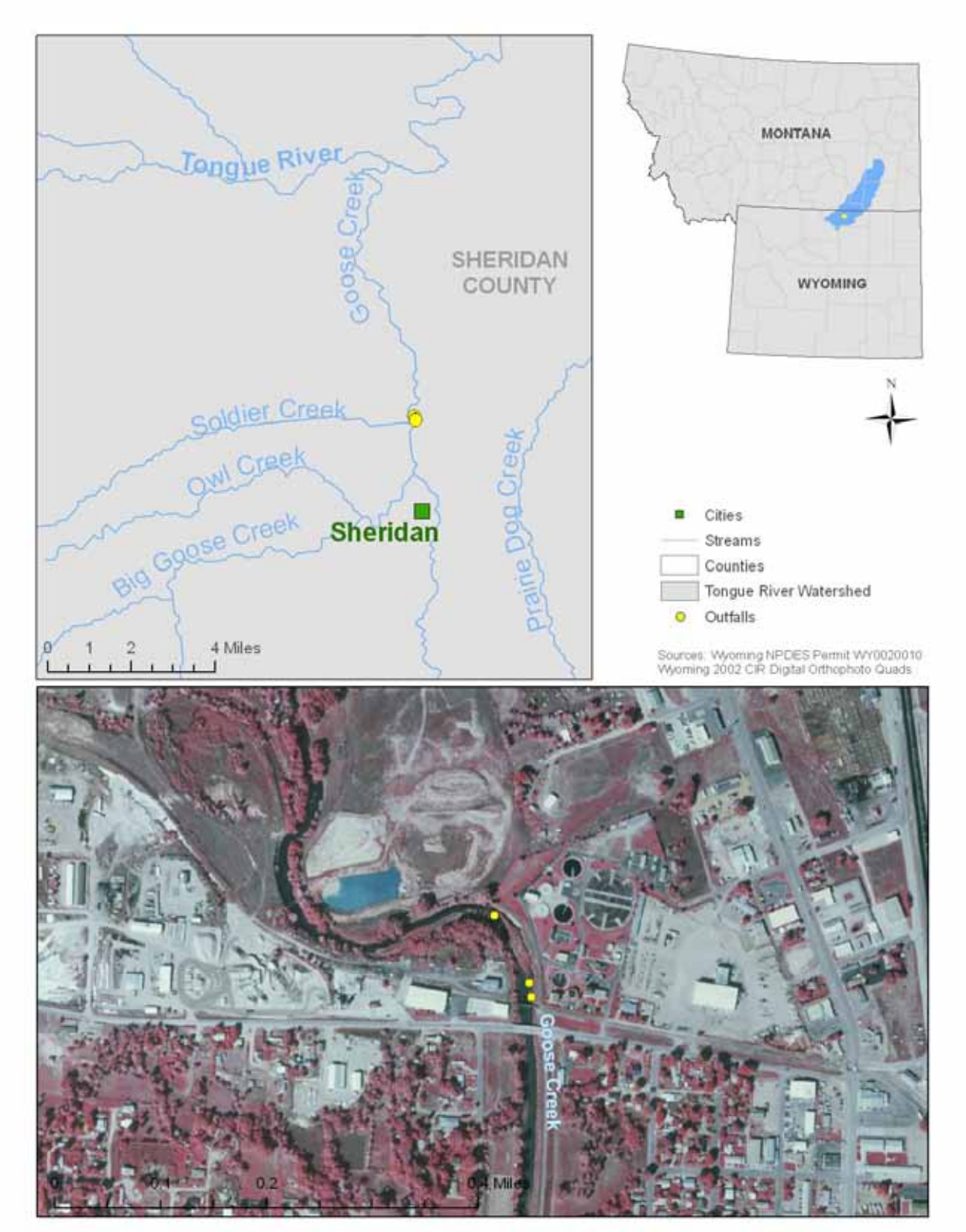

Figure A-8. Location of the Sheridan WWTP and outfalls (Permit # WY0020010).

A.3.2.2 City of Dayton WWTP (WY0020435)

The City of Dayton Wastewater Treatment Lagoon is located just downstream of the City of Dayton, Wyoming (Figure A-9). No information was available regarding the facility's construction date; however, PCS records indicate that it has been in operation at least since May 23, 1983 (USEPA, 2007). The lagoon currently operates under NPDES permit WY0020435, which allows for one primary discharge point into the Tongue River just downstream of the City of Dayton (outfall 001). An underflow drain is also authorized to discharge to the Tongue River (outfall 002).

The treatment facility consists of a three-cell lagoon system with ultraviolet disinfection and aeration in the first cell (WDEQ, 2003a). The permitted flow is 0.2 MGD (0.3 cfs). All permit limits for the facility are shown in Table A-13.

Table A-13. Permit limits for the Dayton Wastewater Treatment Lagoon (Limits as of February 28, 2003.)

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms	#/100 mL	40,358	17,325
Total Suspended Solids	mg/L	300	100
pH	S.U.	6.5-9.0	NA
Total Residual Chlorine	mg/L	1	NA
Flow	MGD	NA	0.2

Outfall monitoring data from the lagoon's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-14.

Table A-14. Summary of the Dayton Wastewater Treatment Lagoon effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Dayton Lagoon (WY0020435)	001	1988 – Present	100%	0.12	NA	NA	NA	NA	NA	11.08

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

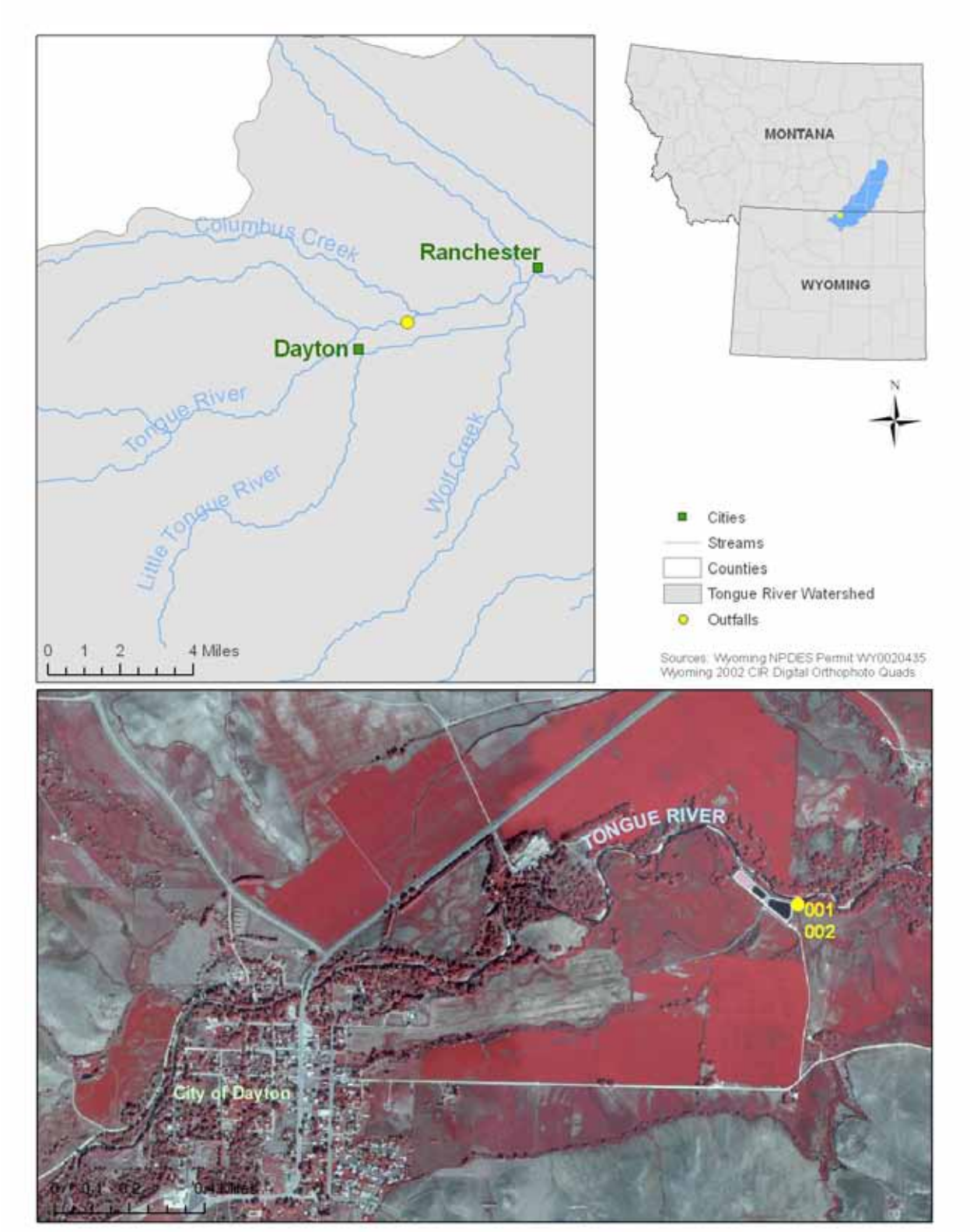

Figure A-9. Location of the Dayton lagoons and outfalls (Permit # WY0020435).

A.3.2.3 City of Ranchester WWTP (WY0022161)

The City of Ranchester Wastewater Treatment Lagoon is located just downstream of the City of Ranchester, Wyoming (Figure A-10). No information was available regarding the facility's construction date; however, PCS records indicate that it has been in operation at least since April 1, 1981 (USEPA, 2007). The lagoon currently operates under NPDES permit WY0022161, which allows for one primary discharge point into the Tongue River just downstream of the City of Ranchester (outfall 001) (WDEQ, 2005b). An underflow drain is also authorized to discharge to the Tongue River (outfalls 002 through 004).

The treatment facility consists of a three-cell lagoon system with a chlorine disinfection system. The lagoon has a permitted flow of 0.179 MGD (0.277 cfs) (WDEQ, 2005b). All permit limits for the facility are shown in Table A-15.

Table A-15. Permit limits for the Ranchester Wastewater Treatment Lagoon (Limits as of March 2, 2005).

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms (May-Sep)	#/100 mL	64,482	30,555
Fecal Coliforms (Oct-Apr)	#/100 mL	51,337	24,328
Total Suspended Solids	mg/L	300	100
pH	S.U.	6.5-9.0	NA
Total Residual Chlorine (May-Sep)	mg/L	1.2	NA
Total Residual Chlorine (Oct-Apr)	mg/L	1.5	
Flow	MGD	NA	0.179

Outfall monitoring data from Ranchester's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-16.

Table A-16. Summary of the Ranchester Wastewater Treatment Lagoon effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Ranchester Lagoon (WY0020435)	001	1990 – Present	100%	0.16	NA	691	NA	NA	NA	9.60

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

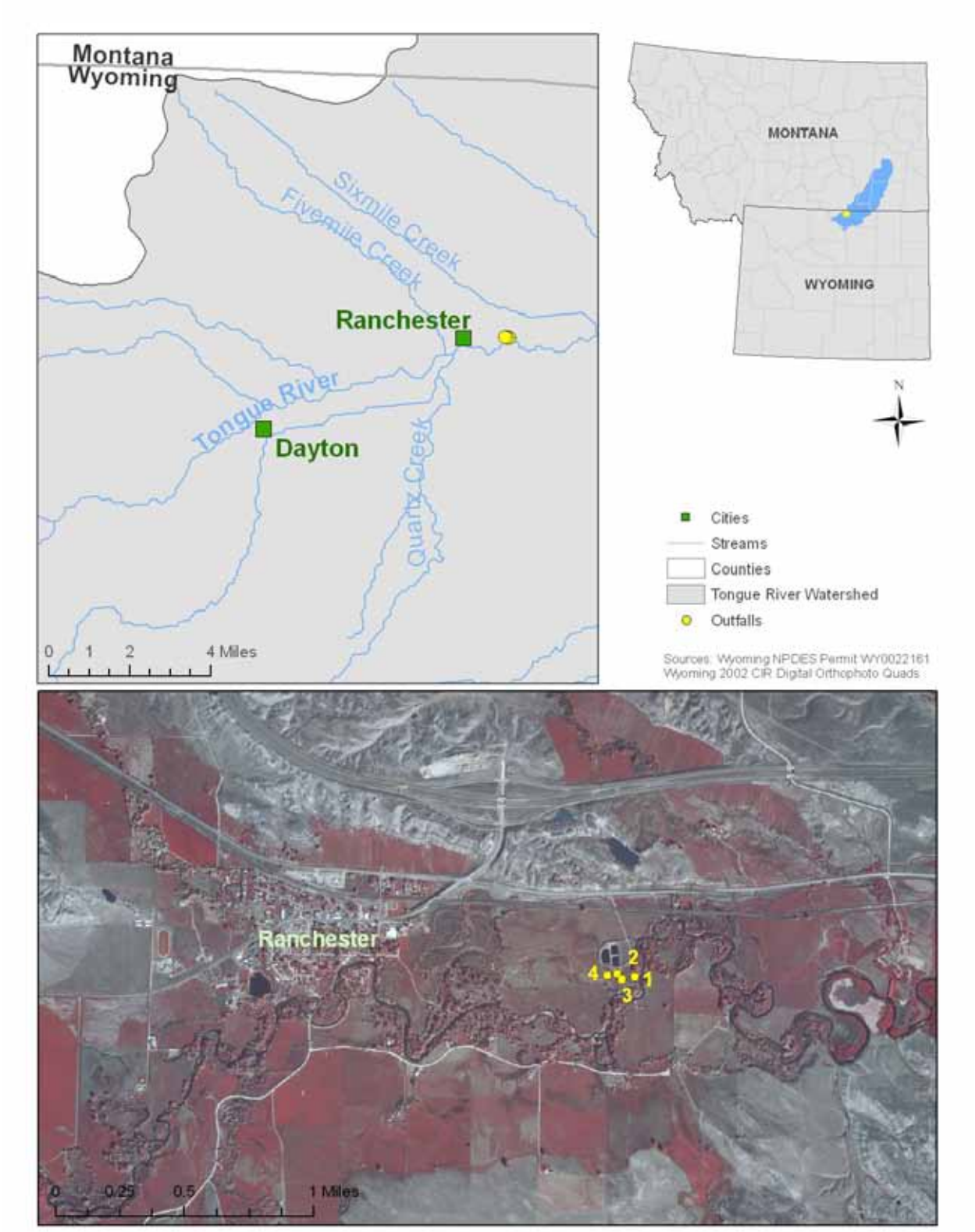

Figure A-10. Location of the Ranchester wastewater treatment lagoons and outfalls (Permit # WY0022161).

A.3.2.4 Big Horn Mountain KOA Lagoon (WY0026441)

The Big Horn Mountain KOA is located approximately 5 miles north of the City of Sheridan, Wyoming (Figure A-11). The facility operates an extended aeration package plant with chlorination disinfection equipment, and discharges to Goose Creek downstream of the City of Sheridan's WWTP discharge (WDEQ, 2003b). No information was available regarding the station's construction date; however, PCS records indicate that it has been in operation at least since July 28, 1981 (USEPA, 2007). The plant currently operates under NPDES permit WY0026441, which allows for one primary discharge point (outfall 001) into Goose Creek near the City of Sheridan, Wyoming. (WDEQ, 2003b). All permit limits for the facility are shown in Table A-17.

Table A-17. Permit limits for the Big Horn Mountain KOA Sewage Treatment Facility (Limits as of May 1, 2003).

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms	#/100 mL	400	200
Total Suspended Solids	mg/L	300	100
pH	S.U.	6.5-9.0	NA
Total Residual Chlorine	mg/L	1.0	NA
Flow	MGD	NA	0.016

Outfall monitoring data from Big Horn Mountain's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-18.

Table A-18. Summary of the Big Horn Mountain Sewage Treatment Plant effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Big Horn Mountain KOA (WY0026441)	001	1990 – Present	100%	0.003	NA	691	NA	NA	NA	2.80

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

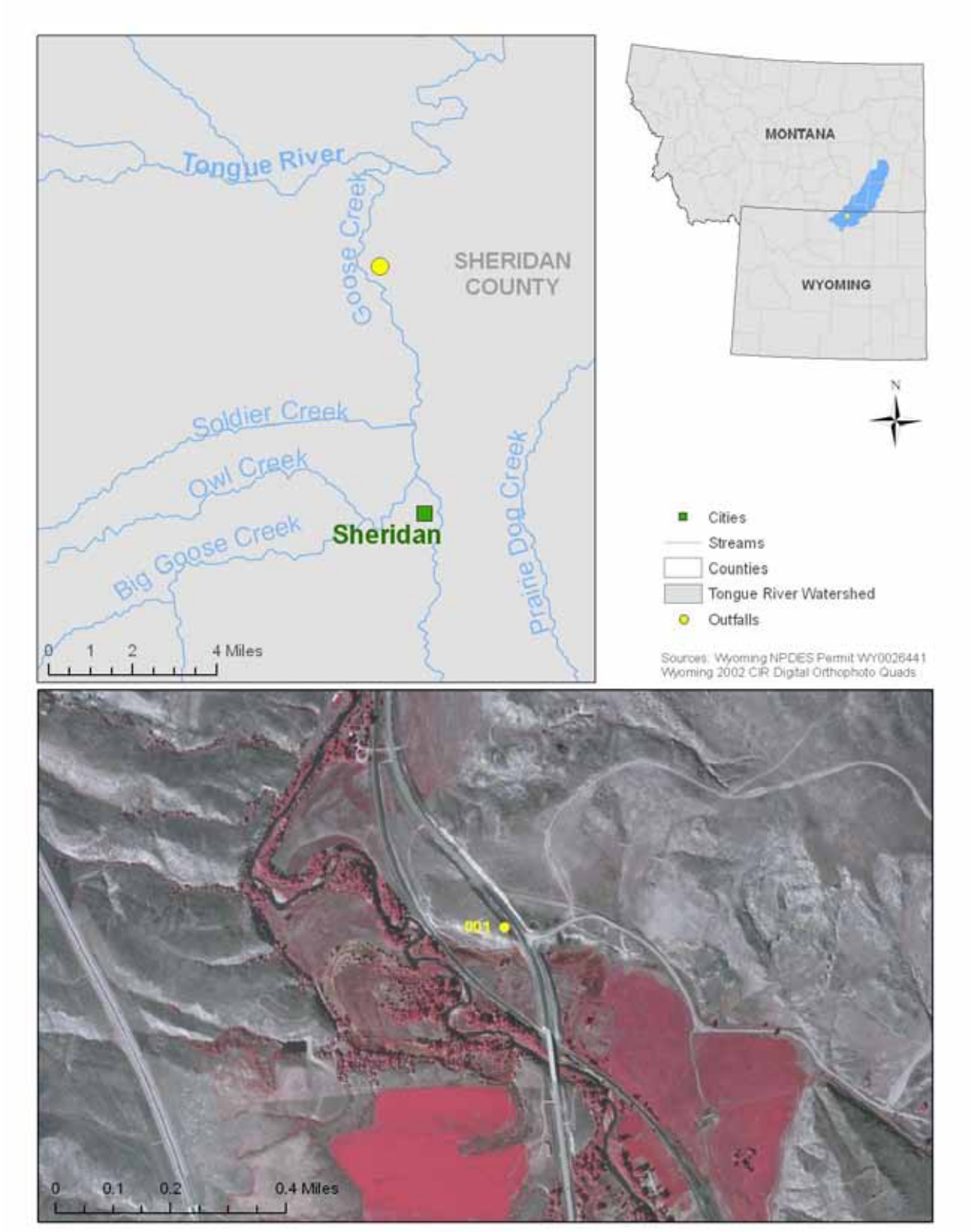

Figure A-11. Location of the Big Horn Mountain KOA wastewater treatment system and outfall (Permit # WY0026441).

A.3.2.5 Powder Horn Ranch, LLC Wastewater Treatment System (WY0036251)

The Powder Horn Ranch Development is located approximately 6 miles south of the City of Sheridan, Wyoming (Figure A-12). Construction began in 2000, and the development will eventually consist of 600 homes, a 27-hole golf course, and club house (WDEQ, 2006b). Wastewater treatment for the facility is provided by an activated sludge package plant. The plant currently operates under NPDES permit WY0036251, which allows for one primary discharge (outfall 001) to a small pond with an overflow to Little Goose Creek. Pond water is used for irrigation, so not all water is discharged into Little Goose Creek (WDEQ, 2006b). All permit limits for the facility are shown in Table A-19.

Table A-19. Permit limits for the Powder Horn Ranch Sewage Treatment Facility (Limits as of May 1, 2006).

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms	#/100 mL	400	200
Total Suspended Solids	mg/L	300	100
pH	S.U.	6.5-9.0	NA
Total Residual Chlorine	mg/L	2.0	NA
Flow	MGD	NA	0.0495

Outfall monitoring data from Powder Horn's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-20.

Table A-20. Summary of the Powder Horn Ranch Sewage Treatment Plant effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Powder Horn Ranch (WY0036251)	001	2001 – Present	100%	0.03	NA	NA	NA	NA	NA	1.0

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

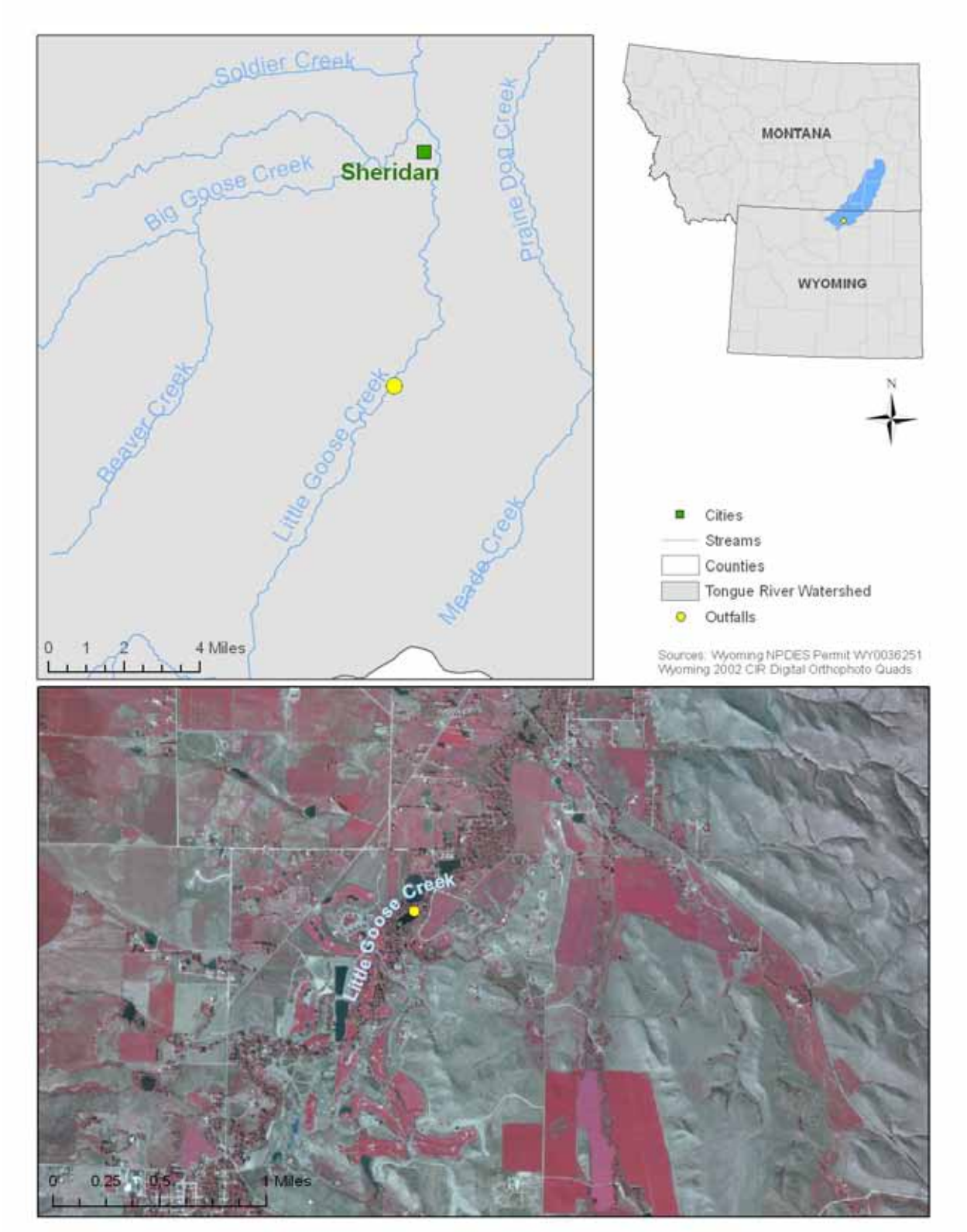

Figure A-12. Location of the Powder Horn Ranch wastewater treatment system and outfall (Permit # WY0036251).

A.3.2.6 Burgess Junction Dump Station (WY0020931)

The Burgess Junction Dump Station is located approximately 0.5 miles east of Burgess Junction in the Bighorn Mountains, Wyoming (Figure A-13). No information was available regarding the station's construction date; however, PCS records indicate that it has been in operation at least since July 28, 1981 (USEPA, 2007). According to the NPDES permit, the dump station is only open from May to September of each year.

Wastewater treatment for the facility is provided by a two-cell non-aerated lagoon system with chlorination equipment (WDEQ, 2004). The facility currently operates under NPDES permit WY0020931, which allows for one primary discharge (outfall 001) to the North Fork of the Tongue River. Two underdrain systems are also permitted to discharge to the North Fork of the Tongue River (outfalls 002 and 003). All permit limits for the facility are shown in Table A-21.

Table A-21. Permit limits for the Burgess Junction Dump Station (Limits as of July 1, 2004).

Parameter	Units	Daily Max	30-Day Average
Biochemical Oxygen Demand (BOD)	mg/L	90	30
Fecal Coliforms	#/100 mL	400	200
Total Suspended Solids	mg/L	300	100
pH	S.U.	6.5-9.0	NA
Total Residual Chlorine	mg/L	0.011	NA
Flow	MGD	NA	0.104

Outfall monitoring data from Burgess Junction's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-22. It should be noted that no flow events have been recorded in the permit compliance system for the primary lagoon outfall (outfall 001); only the underdrain system has reported flows.

Table A-22. Summary of the Burgess Junction Dump Station effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Burgess Junction Dump Station (WY0020931)	001	1981 – Present	0%	NA	NA	NA	NA	NA	NA	NA
	002	1981 – Present	100%	0.063	NA	NA	NA	NA	NA	10.6
	002	1981 – Present	100%	0.002	NA	NA	NA	NA	NA	15.3

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

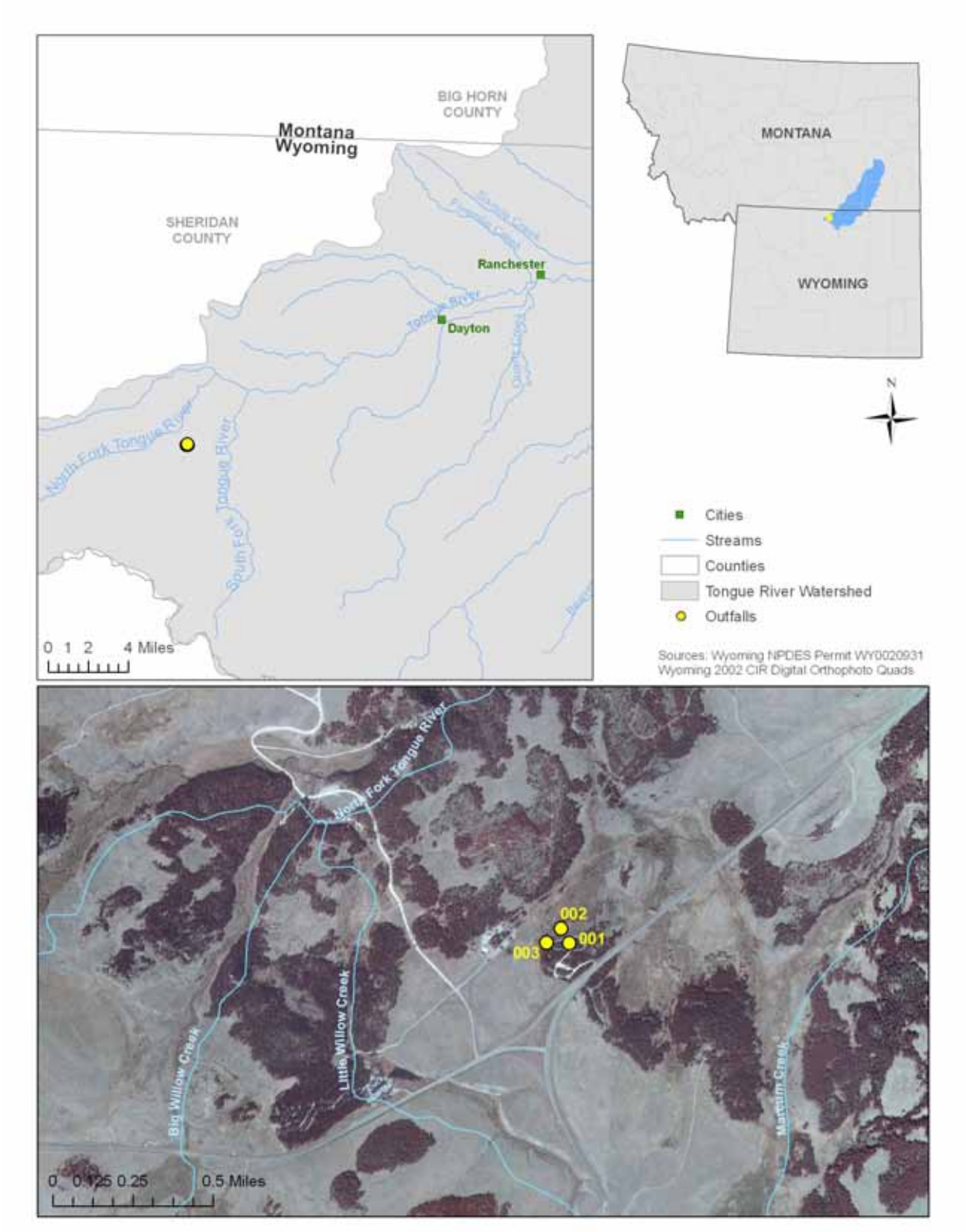

Figure A-13. Location of the Burgess Junction Dump Station (Permit # WY0020931).

A.3.3 Other Permits

Three other facilities in the Tongue River watershed in Wyoming have current or historic permitted surface water discharges – Conoco Phillips Terminal, City of Sheridan Water Treatment Plant, and the Big Horn Coal Mine. The following sections describe the facility locations, permit limits, outfalls, and effluent monitoring data.

A.3.3.1 Conoco Phillips Company (WY0030481)

The Conoco Phillips Sheridan Terminal is a diked tank farm with a product loading area. It is located approximately 9 miles south of Sheridan, Wyoming (Figure A-14). No information was available regarding the facility's construction date; however, PCS records indicate that it has been in operation at least since October 12, 1983 (USEPA, 2007). The facility currently operates under NPDES permit WY0030481, which allows for one primary discharge (outfall 001) to Meade Creek, which is a tributary to Prairie Dog Creek (WDEQ, 2006c). The permit states that discharges are intermittent, and consist of water originating from springs and stormwater runoff located on the facility's grounds. All permit limits for the facility are shown in Table A-23.

Table A-23. Permit limits for the Conoco Phillips Sheridan Terminal (Limits as of May 1, 2006).

Parameter	Units	Daily Max	30-Day Average
Total Petroleum Hydrocarbons (DRO and GRO)	mg/L	10	NA
Benzene	µg/L	1.2	NA
Toluene	µg/L	1,000	NA
Ethylbenzene	µg/L	700	NA
Xylenes	µg/L	10,000	NA
Flow	MGD	NA	NA

Outfall monitoring data from the Conoco Phillips Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-24.

Table A-24. Summary of the Conoco Phillips Sheridan Terminal effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Conoco Phillips Sheridan Terminal (WY0030481)	001	1983 – Present	86%	0.001	NA	NA	NA	NA	NA	NA

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

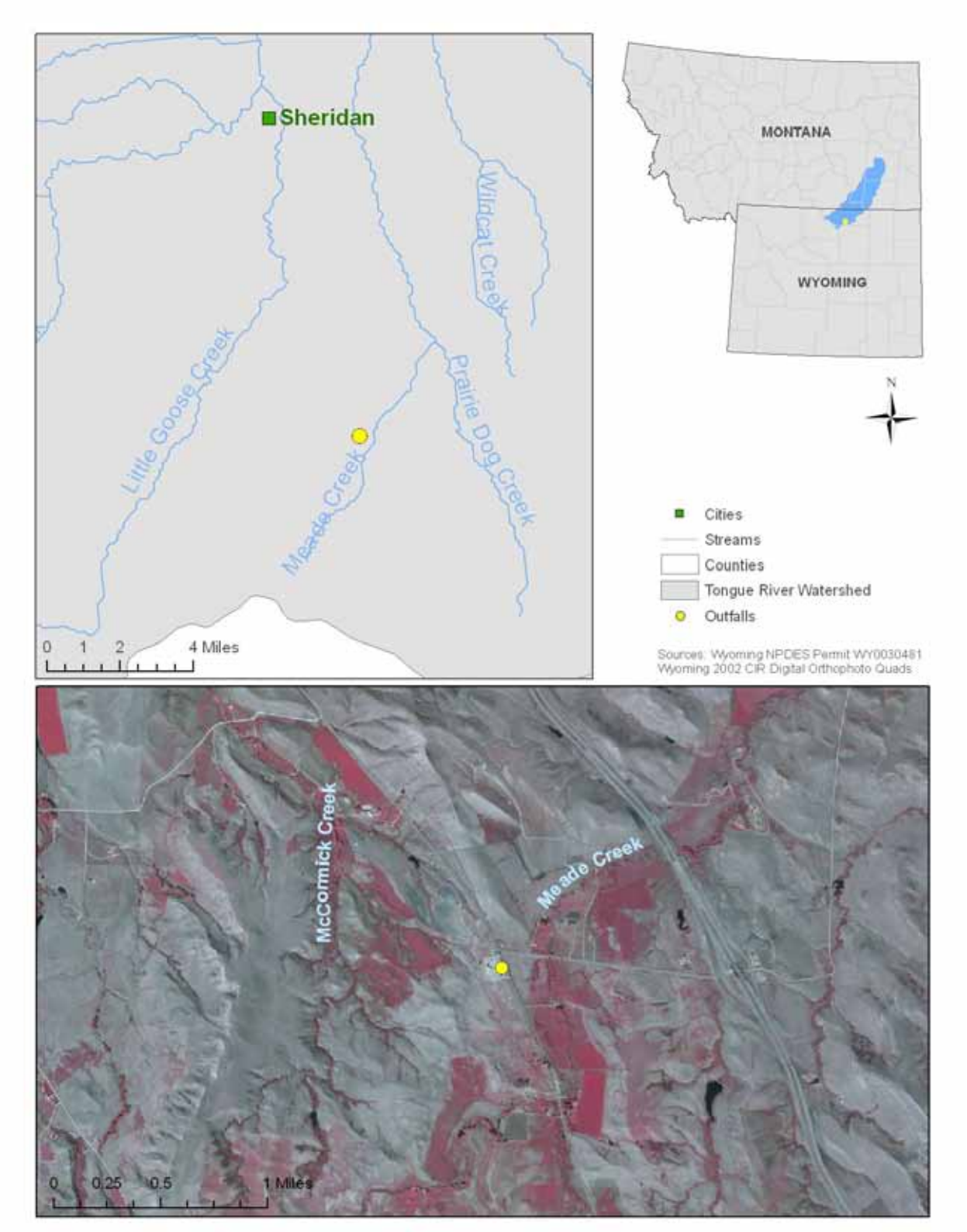

Figure A-14. Location of the ConocoPhillips Sheridan Terminal and outfall (Permit # WY0030481).

A.3.3.2 City of Sheridan Water Treatment Plant (WY0035661 and WY0001392)

The City of Sheridan, Wyoming is the operator of a standard water treatment plant with the basic purpose of clarifying and disinfecting raw surface water for use as potable water (WDEQ, 2006d). The facility is located approximately three miles west of the City of Sheridan (Figure A-15). No information was available regarding the facility's construction date; however, PCS records indicate that it has been in operation since at least January 23, 1981 (USEPA, 2007). Water for the plant is diverted out of Big Goose Creek just downstream of the canyon. Records from the Wyoming State Water Plan indicate that an average of 8.4 cubic feet per second is diverted out of Big Goose Creek (WWDC, 2002). Under normal operations, the plant does not discharge any water. However, the permit allows for effluent discharges from outfall 001 to Gillespie Draw, which is a tributary to Big Goose Creek. Permit limits for the facility are shown in Table A-25.

Table A-25. Permit limits for the Conoco Phillips Sheridan Terminal (Limits as of May 1, 2006).

Parameter	Units	Daily Max	30-Day Average
Total Suspended Solids	mg/L	45	20
Total Residual Chlorine	mg/L	0.019	NA

Outfall monitoring data from the water treatment plant's Discharge Monitoring Reports (DMRs) were downloaded from the EPA Permits Compliance System (PCS) on October 18, 2006 (available online at http://www.epa.gov/enviro/html/pcs/pcs_overview.html). This was supplemented with data provided by Wyoming DEQ in a Microsoft Access database dated January 26, 2007. Outfall data are summarized in Table A-26.

Table A-26. Summary of the City of Sheridan Water Treatment Plant effluent data (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)	NH_3 (mg/L)
Sheridan Water Treatment Plant (WY0001392)	001	1981 – Present	0%	NA	NA	NA	NA	NA	NA	NA

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
NA – Not Available

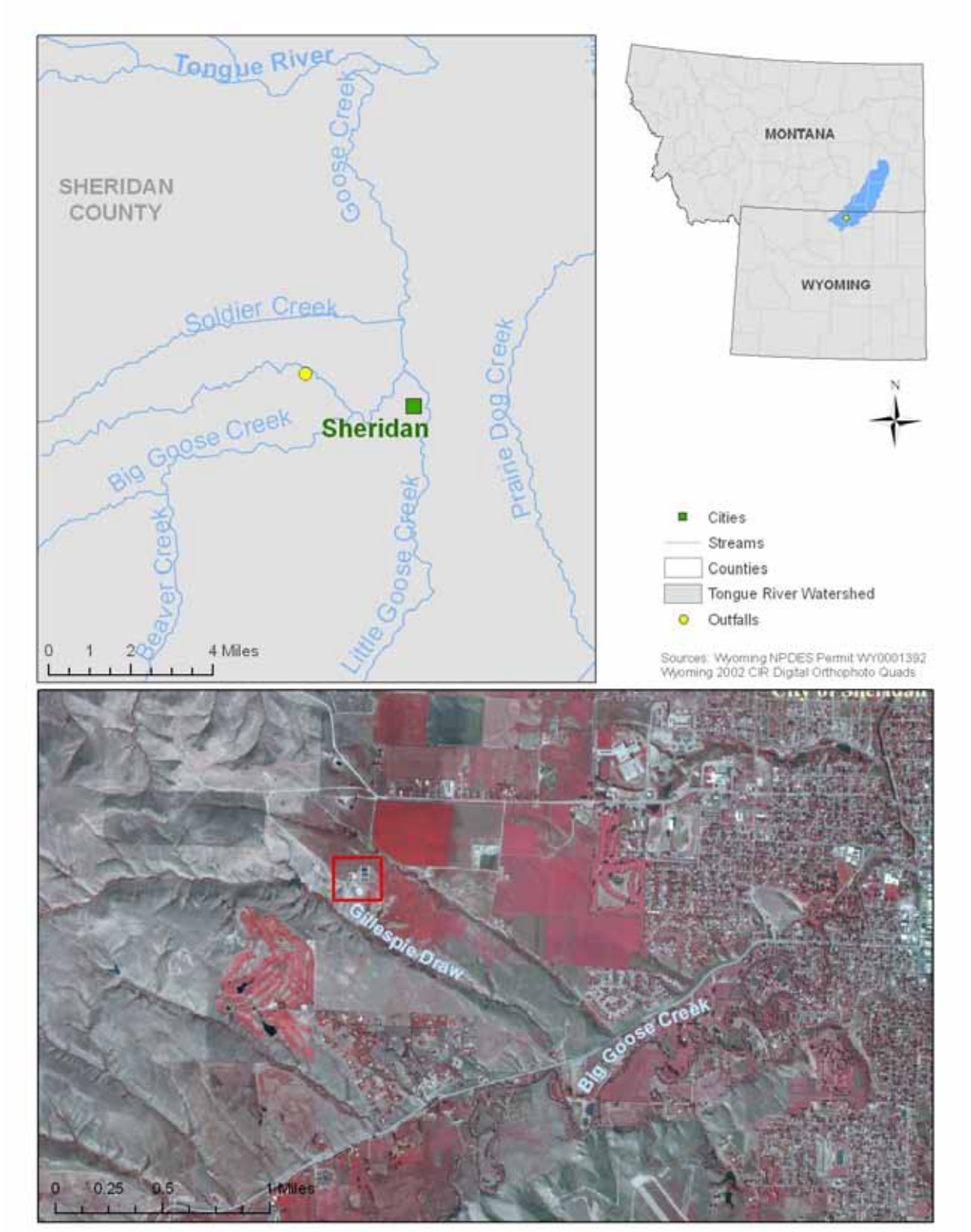

Figure A-15. Location of the Sheridan Water Treatment Plant and outfall (Permit # WY0001392).

A.3.3.3 Big Horn Coal Mine (WY0022519)

The Big Horn Coal Mine is a typical strip mining facility located approximately six miles south of the Montana-Wyoming border at Acme, Wyoming (Figure A-16). Mining operations began in 1943 and ceased in 2000, with reclamation efforts continuing to the present (Committee on Interior and Insular Affairs, 1971) (Kiewit, 2007). The NPDES permit was terminated at the end of mine operations in 2000.

The Big Horn mine was partially located within the stream channels of the Tongue River and Big Goose Creek, both of which were rerouted several times to accommodate mine operations (Committee on Interior and Insular Affairs, 1977) (Gore and Johnson, 1979) (see Figure A-17). Mine spoils are still present in the floodplains of both Goose Creek and the Tongue River, and the Big Horn mine was listed as the source of iron and manganese impairment in Goose Creek by Wyoming DEQ on the 1998 303(d) list. Point source TMDLs for both parameters were completed in 1999.

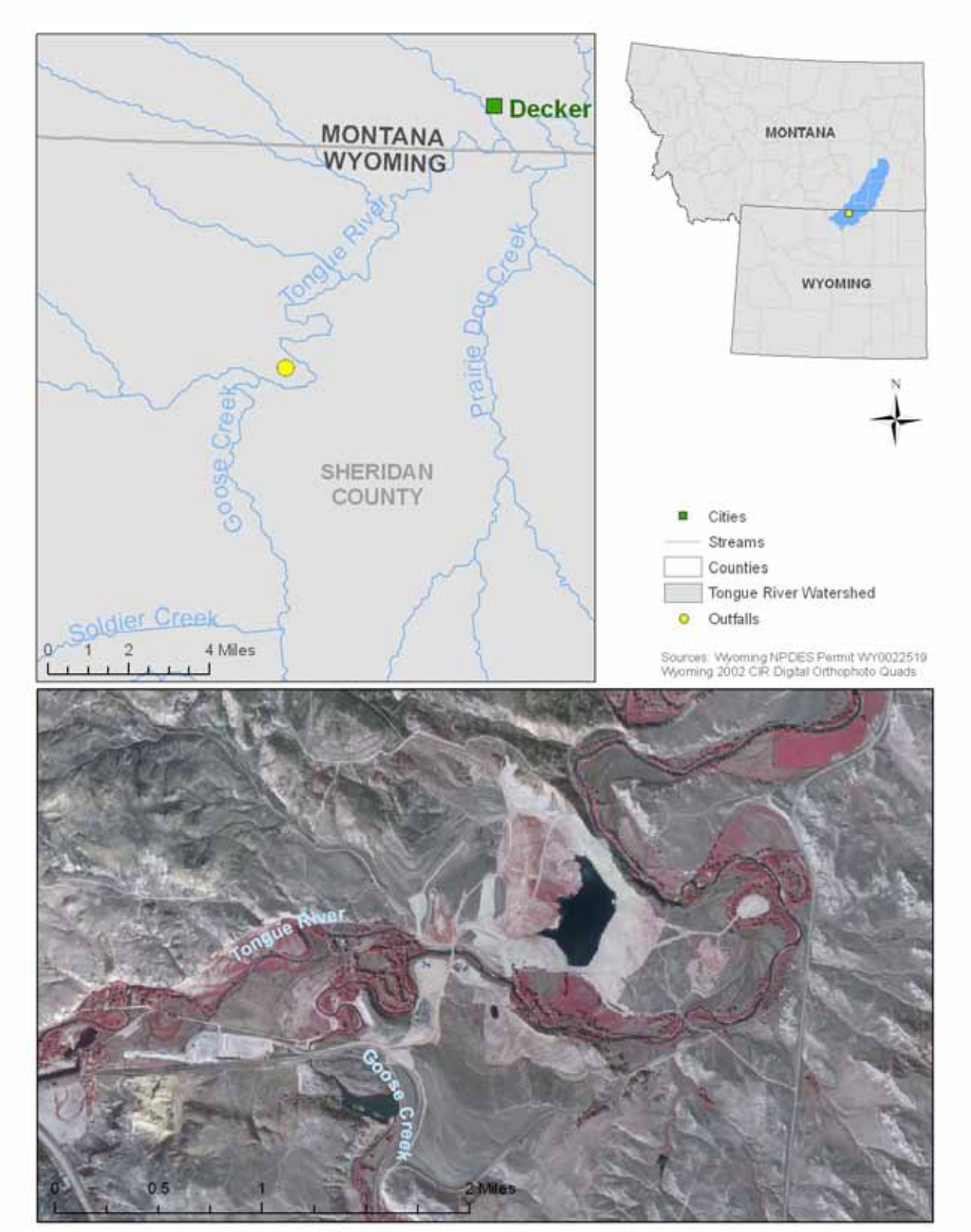

Figure A-16. Location of the Big Horn Coal Mine (Terminated Permit # WY0022519).

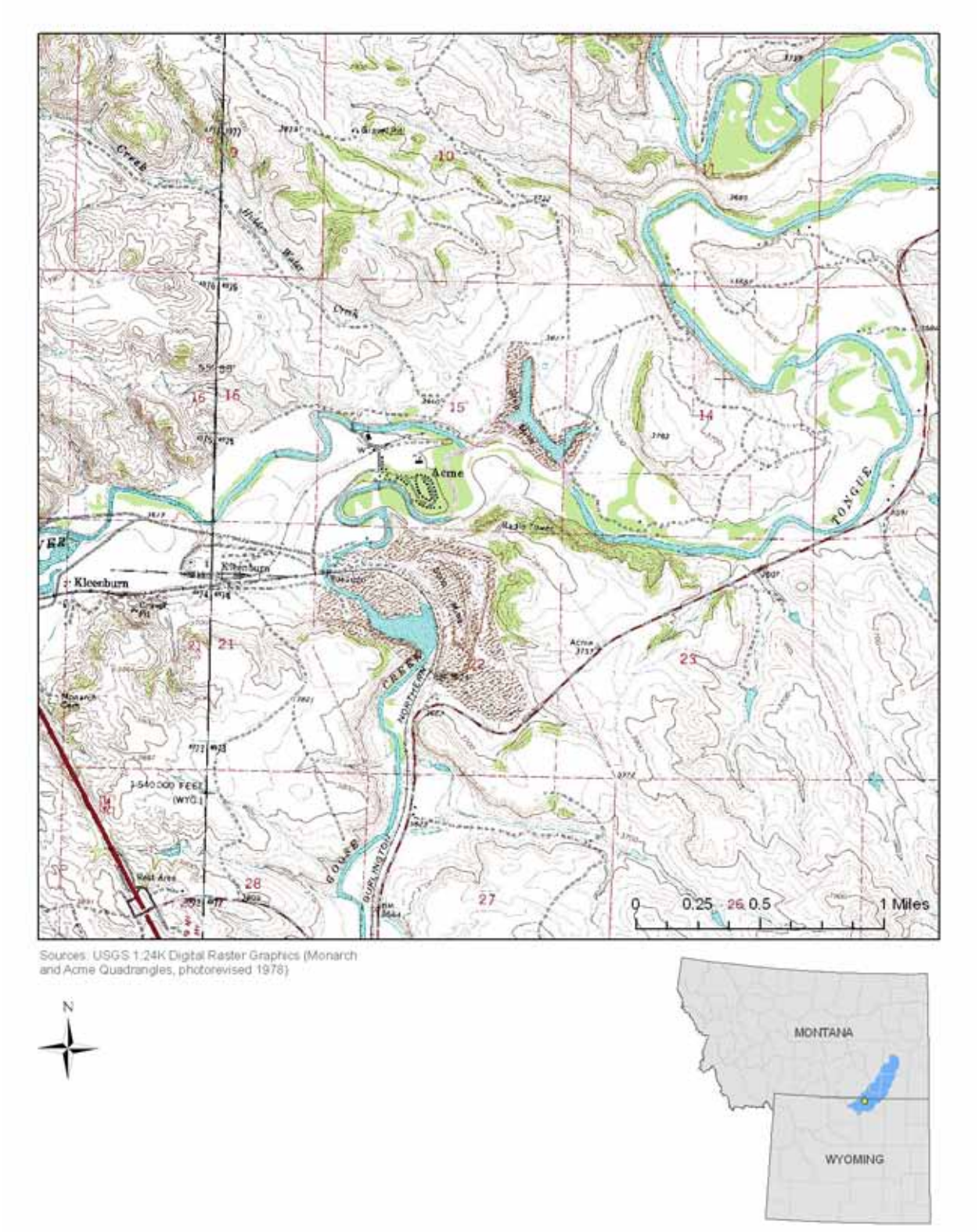

Figure A-17. Location of the Big Horn Coal Mine (circa 1978) showing the rerouting of the Tongue River and Goose Creek.

A.3.4 Wyoming Permits – Summary

Since 1999, there have been 428 permitted outfalls discharging to surface waters of the state of Wyoming. Permits are primarily for CBM facilities and wastewater treatment. CBM development in the Tongue River watershed, Wyoming began in 1999, and new wells continue to be drilled at the time of this report. Flow and water quality varies per CBM outfall. The long term average flow per outfall (average of all outfalls) was 0.68 cubic feet per second, with an average salinity of 1,900 µS/cm and an average SAR of 38.1. Wastewater treatment has been fairly constant since the mid-1980s, although additional facilities have been recently constructed (i.e., Powder Horn Ranch) to accommodate new development. Few salinity and SAR data are available for these facilities. Table A-27 summarizes the discharge data for each facility.

Table A-27. Summary of permitted surface water discharge data in the Tongue River watershed, Wyoming (average values are reported).

Facility	Outfall	Period of Operation	Months with Flow[1]	Flow (cfs)	EC (µS/cm)	TDS (mg/L)	SAR	Total N (mg/L)	Total P (mg/L)
CBM Outfalls (Multiple Permits)[2]	Average of All CBM Outfalls	1999 – Present	100%	0.682	1,900	NA	38.1	NA	NA
Sheridan WWTP (WY0020010)	001	1988 – Present	100%	4.6	838	442	2.73	NA	3.7
Dayton Lagoon (WY0020435)	001	1988 – Present	100%	0.12	NA	NA	NA	NA	NA
Ranchester Lagoon (WY0020435)	001	1990 – Present	100%	0.16	NA	691	NA	NA	NA
Big Horn Mountain KOA (WY0026441)	001	1990 – Present	100%	0.003	NA	691	NA	NA	NA
Powder Horn Ranch (WY0036251)	001	2001 – Present	100%	0.03	NA	NA	NA	NA	NA
Burgess Junction Dump Station (WY0020931)	001	1981 – Present	0%	NA	NA	NA	NA	NA	NA
	002		100%	0.063	NA	NA	NA	NA	NA
	002		100%	0.002	NA	NA	NA	NA	NA
Conoco Phillips Sheridan Terminal (WY0030481)	001	1983 – Present	86%	0.001	NA	NA	NA	NA	NA
Sheridan Water Treatment Plant (WY0001392)	001	1981 – Present	0%	NA	NA	NA	NA	NA	NA

[1]Some outfalls discharged intermittently (e.g., 1 out of 10 months). The percentage of months with a discharge is reported in this column.
[2]The average value from all of the available CBM effluent data (March 1, 1999 to July 1, 2006).
NA – Not Available

A.4 Modeled Outfalls

As described in previous sections, over 400 outfalls have discharged or are currently discharging to surface waterbodies in the Tongue River watershed. DMR data, including both flow and water chemistry information, were obtained from a variety of sources. Outfalls were only included in the LSPC model if the DMR data met two requirements: (1) At least one measured flow was reported in the DMR data, and (2) the time series of DMR data indicated that the outfall continuously discharges (i.e., discharge was reported for most of the months during the available period of record). Based on these two requirements, 435 outfalls were modeled in LSPC. These include 428 CBM outfalls (410 in Wyoming and 18 in Montana), 2 coal mine outfalls, and 5 wastewater treatment plant outfalls. Table A-28 summarizes the permit, outfall, name, and location of each of the modeled outfalls.

Table A-28. Summary of the known permitted surface water discharges in the Tongue River watershed.

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0038563	1	CBM	Badger Creek CBM #1	44.95960	-106.73195	3002
WY0038563	2	CBM	Badger Creek CBM #1	44.95960	-106.73195	3002
WY0038571	1	CBM	Federal 8-21 And 8-22 Mydland CBM Wells	44.92626	-106.86831	3007
WY0038571	2	CBM	Federal 8-21 And 8-22 Mydland CBM Wells	44.92626	-106.86831	3007
WY0038598	1	CBM	Federal 9-23 9-31 9-32 9-33 CBM Wells	44.92626	-106.86831	3007
WY0038598	2	CBM	Federal 9-23 9-31 9-32 9-33 CBM Wells	44.92626	-106.86831	3007
WY0038598	3	CBM	Federal 9-23 9-31 9-32 9-33 CBM Wells	44.92626	-106.86831	3007
WY0038598	4	CBM	Federal 9-23 9-31 9-32 9-33 CBM Wells	44.92626	-106.86831	3007
WY0038598	5	CBM	Federal 9-23 9-31 9-32 9-33 CBM Wells	44.92626	-106.86831	3007
WY0038601	1	CBM	Pilch CBM Field	44.95278	-106.86528	3007
WY0038601	2	CBM	Pilch CBM Field	44.95278	-106.86528	3007
WY0038601	3	CBM	Pilch CBM Field	44.95278	-106.86528	3007
WY0038601	4	CBM	Pilch CBM Field	44.95278	-106.86528	3007
WY0038601	5	CBM	Pilch CBM Field	44.95278	-106.86528	3007
WY0038628	1	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.90656	-106.95553	3019
WY0038628	2	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88857	-106.77954	3007
WY0038628	3	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.90656	-106.95553	3019
WY0038628	4	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.90656	-106.95553	3019
WY0038628	5	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88365	-106.95643	3021
WY0038628	6	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88519	-106.95636	3021
WY0038628	7	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88460	-106.94789	3021
WY0038628	8	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.87825	-106.96067	3021
WY0038628	9	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.87888	-106.97395	3022
WY0038628	10	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.87085	-106.96085	3022
WY0038628	11	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.87085	-106.96085	3022
WY0038628	12	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.87998	-106.95273	3021
WY0038628	13	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88127	-106.95277	3021
WY0038628	14	CBM	Wrench Ranch - Goose Creek On-Channel	44.87463	-106.94368	3021

Permit	Outfall	Type	Name	Lat	Long	Subbasin
			CBM			
WY0038636	1	CBM	Wrench Ranch - Tongue River On-Channel CBM	44.90643	-106.95567	3019
WY0038636	2	CBM	Wrench Ranch - Tongue River On-Channel CBM	44.90643	-106.95567	3019
WY0038636	3	CBM	Wrench Ranch - Tongue River On-Channel CBM	44.90643	-106.95567	3019
WY0038644	1	CBM	Acme CBM Project C	44.90656	-106.95553	3019
WY0038644	2	CBM	Acme CBM Project C	44.88857	-106.77954	3007
WY0038644	3	CBM	Acme CBM Project C	44.90656	-106.95553	3019
WY0038644	4	CBM	Acme CBM Project C	44.90656	-106.95553	3019
WY0038652	1	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88857	-106.77954	3007
WY0038652	2	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88365	-106.95643	3021
WY0038652	3	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88519	-106.95636	3021
WY0038652	4	CBM	Wrench Ranch - Goose Creek On-Channel CBM	44.88460	-106.94789	3021
WY0038857	1	CBM	Taylor Reservoir	44.93140	-106.84580	3007
WY0038881	1	CBM	Federal 24-13, 24-14, 24-23, 24-24 CBM Wells	44.92626	-106.86831	3007
WY0040568	1	CBM	Prairie Dog Creek CBM Project	44.95889	-106.83440	3007
WY0040568	2	CBM	Prairie Dog Creek CBM Project	44.95410	-106.83500	3007
WY0040568	3	CBM	Prairie Dog Creek CBM Project	44.95111	-106.83583	3007
WY0040568	4	CBM	Prairie Dog Creek CBM Project	44.94806	-106.84056	3007
WY0040568	5	CBM	Prairie Dog Creek CBM Project	44.94639	-106.84528	3007
WY0040568	6	CBM	Prairie Dog Creek CBM Project	44.94056	-106.83528	3007
WY0040568	7	CBM	Prairie Dog Creek CBM Project	44.94278	-106.85222	3007
WY0040568	8	CBM	Prairie Dog Creek CBM Project	44.93861	-106.85444	3007
WY0040568	9	CBM	Prairie Dog Creek CBM Project	44.93444	-106.85500	3007
WY0040568	10	CBM	Prairie Dog Creek CBM Project	44.93583	-106.87111	3007
WY0040568	11	CBM	Prairie Dog Creek CBM Project	44.94056	-106.88389	3007
WY0040568	12	CBM	Prairie Dog Creek CBM Project	44.93972	-106.88056	3007
WY0040568	13	CBM	Prairie Dog Creek CBM Project	44.94278	-106.88500	3007
WY0040568	14	CBM	Prairie Dog Creek CBM Project	44.94470	-106.87200	3007
WY0040568	15	CBM	Prairie Dog Creek CBM Project	44.94452	-106.87565	3007
WY0040568	16	CBM	Prairie Dog Creek CBM Project	44.94452	-106.87877	3007
WY0040568	17	CBM	Prairie Dog Creek CBM Project	44.94840	-106.87300	3007
WY0040568	18	CBM	Prairie Dog Creek CBM Project	44.95222	-106.87361	3007
WY0040568	19	CBM	Prairie Dog Creek CBM Project	44.95180	-106.87400	3007
WY0040568	20	CBM	Prairie Dog Creek CBM Project	44.95278	-106.86521	3007
WY0040568	21	CBM	Prairie Dog Creek CBM Project	44.95630	-106.86820	3007
WY0046531	1	CBM	Taylor	44.92017	-106.88239	3007
WY0046531	2	CBM	Taylor	44.91397	-106.88147	3007
WY0046531	3	CBM	Taylor	44.91378	-106.87106	3007
WY0046531	4	CBM	Taylor	44.91136	-106.86942	3007
WY0046531	5	CBM	Taylor	44.90292	-106.86903	3007
WY0046531	6	CBM	Taylor	44.90025	-106.88900	3007
WY0046531	7	CBM	Taylor	44.90011	-106.88222	3007
WY0046531	8	CBM	Taylor	44.89594	-106.89278	3007
WY0046531	9	CBM	Taylor	44.90500	-106.89050	3007

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0046531	10	CBM	Taylor	44.90650	-106.87734	3007
WY0046540	1	CBM	Dunning	44.96607	-106.90105	3019
WY0046540	2	CBM	Dunning	44.96500	-106.89783	3019
WY0046540	3	CBM	Dunning	44.96181	-106.89919	3019
WY0046540	4	CBM	Dunning	44.95384	-106.90233	3019
WY0046540	5	CBM	Dunning	44.95064	-106.91244	3019
WY0046540	6	CBM	Dunning	44.94808	-106.89673	3019
WY0046540	7	CBM	Dunning	44.93467	-106.91472	3019
WY0046540	8	CBM	Dunning	44.94397	-106.90483	3019
WY0046558	1	CBM	Trembath	44.96734	-106.82864	3007
WY0046558	2	CBM	Trembath	44.96087	-106.83354	3007
WY0046558	3	CBM	Trembath	44.96012	-106.81714	3007
WY0046558	4	CBM	Trembath	44.95706	-106.81017	3007
WY0046566	1	CBM	Dewey	44.97181	-106.85597	3007
WY0046566	2	CBM	Dewey	44.96716	-106.85786	3007
WY0046566	3	CBM	Dewey	44.96705	-106.86520	3007
WY0046566	4	CBM	Dewey	44.96995	-106.86232	3007
WY0046566	5	CBM	Dewey	44.96810	-106.84643	3007
WY0046574	1	CBM	LPD	44.93244	-106.87458	3007
WY0046574	2	CBM	LPD	44.93022	-106.89044	3007
WY0046574	3	CBM	LPD	44.92589	-106.88022	3007
WY0046574	4	CBM	LPD	44.92270	-106.88646	3007
WY0046574	5	CBM	LPD	44.92261	-106.89403	3007
WY0046574	6	CBM	LPD	44.91253	-106.88518	3007
WY0046574	7	CBM	LPD	44.91382	-106.89176	3007
WY0046574	8	CBM	LPD	44.91824	-106.88928	3007
WY0046574	9	CBM	LPD	44.92826	-106.86831	3007
WY0046574	10	CBM	LPD	44.92583	-106.89003	3007
WY0046841	3	CBM	Youngs Creek Drainage	44.97167	-106.94805	3019
WY0046841	5	CBM	Youngs Creek Drainage	44.97668	-106.97498	3019
WY0046850	1	CBM	Intermittent North Drainage	44.99340	-106.91790	3017
WY0047066	1	CBM	Wrench Ranch Project-Goose Creek Drainage	44.90656	-106.95553	3019
WY0047066	2	CBM	Wrench Ranch Project-Goose Creek Drainage	44.88857	-106.77954	3007
WY0047066	3	CBM	Wrench Ranch Project-Goose Creek Drainage	44.90656	-106.95553	3019
WY0047066	4	CBM	Wrench Ranch Project-Goose Creek Drainage	44.90656	-106.95553	3019
WY0047074	1	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87670	-106.92839	3019
WY0047074	2	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87631	-106.92257	3019
WY0047074	3	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87326	-106.92917	3019
WY0047074	4	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.86275	-106.92766	3019
WY0047074	5	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.86784	-106.93038	3019
WY0047074	6	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87831	-106.91708	3019
WY0047074	7	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87767	-106.91469	3019
WY0047074	8	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87964	-106.90736	3008
WY0047074	9	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.88278	-106.90486	3008
WY0047074	10	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87547	-106.90558	3008
WY0047074	11	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87333	-106.90625	3008
WY0047074	12	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87117	-106.89556	3008

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0047074	13	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87181	-106.90056	3008
WY0047074	14	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.86964	-106.90700	3008
WY0047074	15	CBM	Wrench Ranch Project-Beatty Gulch Drainage	44.87353	-106.88975	3008
WY0047082	1	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.85996	-106.90438	3008
WY0047082	2	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.87320	-106.91798	3019
WY0047082	3	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86367	-106.89986	3008
WY0047082	4	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86653	-106.89550	3008
WY0047082	5	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86122	-106.91250	3008
WY0047082	6	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86497	-106.90972	3008
WY0047082	7	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86419	-106.89692	3008
WY0047082	8	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.85997	-106.91806	3008
WY0047082	9	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86831	-106.91656	3008
WY0047082	10	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86814	-106.89300	3008
WY0047082	11	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86764	-106.88872	3008
WY0047082	12	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86764	-106.88575	3008
WY0047082	13	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.85856	-106.91506	3008
WY0047082	14	CBM	Wrench Ranch Project-Prairie Dog Creek Drainage	44.86064	-106.89364	3008
WY0047180	1	CBM	Tongue River Project Unnamed North Ephemeral Drainage	44.99466	-106.83872	3014
WY0047180	2	CBM	Tongue River Project Unnamed North Ephemeral Drainage	44.99466	-106.83872	3014
WY0047198	1	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.97765	-106.85402	3007
WY0047198	2	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.97560	-106.87368	3017
WY0047198	3	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.98485	-106.86972	3016
WY0047198	4	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.97914	-106.86226	3016
WY0047198	5	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.98536	-106.85716	3016
WY0047198	6	CBM	Tongue River Project-Unnamed West Ephemeral Drainage	44.97592	-106.86678	3016
WY0048038	1	CBM	Tongue River Project-West (11)	44.97012	-106.89744	3017
WY0048038	2	CBM	Tongue River Project-West (11)	44.97318	-106.89500	3017
WY0048038	3	CBM	Tongue River Project-West (11)	44.96340	-106.88959	3017
WY0049123	1	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.95583	-106.77440	3002
WY0049123	2	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.95389	-106.77528	3002
WY0049123	3	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.95417	-106.77194	3002
WY0049123	4	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.95250	-106.77111	3002
WY0049123	5	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.94833	-106.77111	3002
WY0049123	6	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.94111	-106.76667	3002

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0049123	7	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.94111	-106.76111	3002
WY0049123	8	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.95472	-106.77361	3002
WY0049123	9	CBM	Tongue River Proj Upper Little Badger Crk Drainage	44.94861	-106.76750	3002
WY0049280	1	CBM	Little Badger-Seven Brothers CBM	44.99028	-106.79972	3002
WY0049280	2	CBM	Little Badger-Seven Brothers CBM	44.98833	-106.80056	3002
WY0049280	3	CBM	Little Badger-Seven Brothers CBM	44.97194	-106.80167	3002
WY0049280	4	CBM	Little Badger-Seven Brothers CBM	44.96806	-106.80222	3002
WY0049280	5	CBM	Little Badger-Seven Brothers CBM	44.97194	-106.79528	3002
WY0049280	6	CBM	Little Badger-Seven Brothers CBM	44.97028	-106.79500	3002
WY0049280	7	CBM	Little Badger-Seven Brothers CBM	44.96528	-106.78861	3002
WY0049280	8	CBM	Little Badger-Seven Brothers CBM	44.96139	-106.79139	3002
WY0049280	9	CBM	Little Badger-Seven Brothers CBM	44.98278	-106.81639	3006
WY0049280	10	CBM	Little Badger-Seven Brothers CBM	44.96361	-106.78667	3002
WY0050571	1	CBM	Pod B Water Treatment Facility	44.94432	-106.85723	3007
WY0051080	2	CBM	Hutton Option 1 Permit	44.85409	-106.89768	3008
WY0051080	3	CBM	Hutton Option 1 Permit	44.83532	-106.91139	3008
WY0051471	1	CBM	Wrench Ranch - Off Channel	44.89694	-106.96389	3019
WY0051471	2	CBM	Wrench Ranch - Off Channel	44.89333	-106.96389	3021
WY0051489	1	CBM	Brinkerhoff 23 Option 2	44.89975	-106.84190	3007
WY0051489	2	CBM	Brinkerhoff 23 Option 2	44.89594	-106.83881	3007
WY0051489	3	CBM	Brinkerhoff 23 Option 2	44.90377	-106.84406	3007
WY0051489	4	CBM	Brinkerhoff 23 Option 2	44.90467	-106.83775	3007
WY0051489	5	CBM	Brinkerhoff 23 Option 2	44.90257	-106.84348	3007
WY0051489	6	CBM	Brinkerhoff 23 Option 2	44.90476	-106.84860	3007
WY0051497	1	CBM	Brinkerhoff 6 Option 2	44.98875	-106.82497	3006
WY0051497	7	CBM	Brinkerhoff 6 Option 2	44.98875	-106.82497	3006
WY0051497	8	CBM	Brinkerhoff 6 Option 2	44.98875	-106.82497	3006
WY0051705	1	CBM	Brinkerhoff 17 & 19 Option 2	44.93882	-106.79680	3007
WY0051705	2	CBM	Brinkerhoff 17 & 19 Option 2	44.93687	-106.79631	3007
WY0051705	3	CBM	Brinkerhoff 17 & 19 Option 2	44.92704	-106.77387	3007
WY0051705	4	CBM	Brinkerhoff 17 & 19 Option 2	44.92218	-106.78391	3007
WY0051705	5	CBM	Brinkerhoff 17 & 19 Option 2	44.91754	-106.77607	3007
WY0051705	6	CBM	Brinkerhoff 17 & 19 Option 2	44.91876	-106.76464	3007
WY0051705	7	CBM	Brinkerhoff 17 & 19 Option 2	44.91103	-106.77491	3007
WY0051705	8	CBM	Brinkerhoff 17 & 19 Option 2	44.91133	-106.76164	3007
WY0051705	9	CBM	Brinkerhoff 17 & 19 Option 2	44.90375	-106.76710	3007
WY0051705	10	CBM	Brinkerhoff 17 & 19 Option 2	44.90108	-106.76660	3007
WY0051705	11	CBM	Brinkerhoff 17 & 19 Option 2	44.90052	-106.75697	3007
WY0051705	12	CBM	Brinkerhoff 17 & 19 Option 2	44.89743	-106.75780	3007
WY0051705	13	CBM	Brinkerhoff 17 & 19 Option 2	44.89831	-106.77121	3007
WY0051705	14	CBM	Brinkerhoff 17 & 19 Option 2	44.89641	-106.76684	3007
WY0051705	15	CBM	Brinkerhoff 17 & 19 Option 2	44.89449	-106.76728	3007
WY0051705	16	CBM	Brinkerhoff 17 & 19 Option 2	44.86930	-106.78395	3007
WY0051705	17	CBM	Brinkerhoff 17 & 19 Option 2	44.89060	-106.79644	3007
WY0051705	18	CBM	Brinkerhoff 17 & 19 Option 2	44.89837	-106.79620	3007
WY0051705	19	CBM	Brinkerhoff 17 & 19 Option 2	44.89815	-106.78580	3007

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0051705	20	CBM	Brinkerhoff 17 & 19 Option 2	44.90692	-106.77571	3007
WY0051705	21	CBM	Brinkerhoff 17 & 19 Option 2	44.90736	-106.77257	3007
WY0051705	22	CBM	Brinkerhoff 17 & 19 Option 2	44.90542	-106.80270	3007
WY0051705	23	CBM	Brinkerhoff 17 & 19 Option 2	44.90758	-106.79930	3007
WY0051705	24	CBM	Brinkerhoff 17 & 19 Option 2	44.90853	-106.80408	3007
WY0051705	25	CBM	Brinkerhoff 17 & 19 Option 2	44.91147	-106.80508	3007
WY0051705	26	CBM	Brinkerhoff 17 & 19 Option 2	44.91233	-106.80680	3007
WY0051705	27	CBM	Brinkerhoff 17 & 19 Option 2	44.91456	-106.78980	3007
WY0051705	28	CBM	Brinkerhoff 17 & 19 Option 2	44.89666	-106.81240	3007
WY0051705	29	CBM	Brinkerhoff 17 & 19 Option 2	44.93018	-106.78980	3007
WY0051705	30	CBM	Brinkerhoff 17 & 19 Option 2	44.87271	-106.78700	3007
WY0051705	31	CBM	Brinkerhoff 17 & 19 Option 2	44.94384	-106.79237	3007
WY0051705	32	CBM	Brinkerhoff 17 & 19 Option 2	44.92823	-106.78486	3007
WY0051705	33	CBM	Brinkerhoff 17 & 19 Option 2	44.92640	-106.78669	3007
WY0051799	1	CBM	Hape 14 Containment Facility	44.82548	-106.82305	3010
WY0051799	2	CBM	Hape 14 Containment Facility	44.82800	-106.82338	3010
WY0051799	3	CBM	Hape 14 Containment Facility	44.83236	-106.82481	3010
WY0051799	4	CBM	Hape 14 Containment Facility	44.82117	-106.81401	3010
WY0051799	5	CBM	Hape 14 Containment Facility	44.83280	-106.82230	3010
WY0051811	1	CBM	Hape 14B Option 2	44.82400	-106.83662	3010
WY0051811	2	CBM	Hape 14B Option 2	44.82247	-106.83304	3010
WY0051811	3	CBM	Hape 14B Option 2	44.82133	-106.83007	3010
WY0051811	4	CBM	Hape 14B Option 2	44.82206	-106.82438	3010
WY0051811	5	CBM	Hape 14B Option 2	44.81871	-106.81341	3010
WY0051811	6	CBM	Hape 14B Option 2	44.82254	-106.81748	3010
WY0051977	1	CBM	AC Ranch N & E Option 2	44.89296	-106.87015	3007
WY0051977	2	CBM	AC Ranch N & E Option 2	44.89007	-106.86833	3007
WY0051977	3	CBM	AC Ranch N & E Option 2	44.89048	-106.87995	3007
WY0051977	4	CBM	AC Ranch N & E Option 2	44.88510	-106.87591	3008
WY0051977	5	CBM	AC Ranch N & E Option 2	44.88441	-106.87182	3008
WY0051977	6	CBM	AC Ranch N & E Option 2	44.88220	-106.88225	3008
WY0051977	7	CBM	AC Ranch N & E Option 2	44.88302	-106.87817	3008
WY0051977	8	CBM	AC Ranch N & E Option 2	44.86875	-106.83816	3010
WY0051977	9	CBM	AC Ranch N & E Option 2	44.88003	-106.86570	3008
WY0051977	10	CBM	AC Ranch N & E Option 2	44.87968	-106.85956	3008
WY0052043	1	CBM	AC Ranch N & E Option 1B	44.84689	-106.84389	3010
WY0052132	1	CBM	AC Ranch Central Non-Discharging Option 2	44.81063	-106.88184	3008
WY0052132	2	CBM	AC Ranch Central Non-Discharging Option 2	44.80725	-106.87940	3008
WY0052132	3	CBM	AC Ranch Central Non-Discharging Option 2	44.80978	-106.86830	3008
WY0052132	4	CBM	AC Ranch Central Non-Discharging Option 2	44.78260	-106.85287	3008
WY0052141	1	CBM	AC Ranch Central Option 2	44.81005	-106.85558	3008
WY0052141	2	CBM	AC Ranch Central Option 2	44.77985	-106.85093	3008
WY0052141	3	CBM	AC Ranch Central Option 2	44.77723	-106.83560	3008
WY0052141	4	CBM	AC Ranch Central Option 2	44.77262	-106.83818	3008
WY0052345	1	CBM	Pipeline Ridge Project (On-Channel Portion)	44.74540	-106.73990	3013
WY0052345	2	CBM	Pipeline Ridge Project (On-Channel Portion)	44.76090	-106.73150	3012
WY0052345	3	CBM	Pipeline Ridge Project (On-Channel Portion)	44.76520	-106.71160	3012

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0052345	4	CBM	Pipeline Ridge Project (On-Channel Portion)	44.76820	-106.73460	3012
WY0052345	5	CBM	Pipeline Ridge Project (On-Channel Portion)	44.77040	-106.72830	3012
WY0052345	6	CBM	Pipeline Ridge Project (On-Channel Portion)	44.77530	-106.72940	3012
WY0052345	7	CBM	Pipeline Ridge Project (On-Channel Portion)	44.74960	-106.72600	3013
WY0052407	1	CBM	Antelope CBM Project	44.98304	-106.43533	1105
WY0052407	2	CBM	Antelope CBM Project	44.98093	-106.42524	1105
WY0052407	3	CBM	Antelope CBM Project	44.98509	-106.41367	1104
WY0052407	4	CBM	Antelope CBM Project	44.98112	-106.41003	1104
WY0052407	5	CBM	Antelope CBM Project	44.98424	-106.38778	1104
WY0052407	6	CBM	Antelope CBM Project	44.97373	-106.38778	1104
WY0052407	7	CBM	Antelope CBM Project	44.97790	-106.40769	1104
WY0052407	8	CBM	Antelope CBM Project	44.97308	-106.41579	1104
WY0052407	9	CBM	Antelope CBM Project	44.96725	-106.40958	1104
WY0052407	10	CBM	Antelope CBM Project	44.97400	-106.43066	1105
WY0052407	11	CBM	Antelope CBM Project	44.96268	-106.42877	1105
WY0052407	12	CBM	Antelope CBM Project	44.95628	-106.42654	1105
WY0052407	13	CBM	Antelope CBM Project	44.94977	-106.43506	1105
WY0052407	14	CBM	Antelope CBM Project	44.96318	-106.40710	1104
WY0052407	15	CBM	Antelope CBM Project	44.95133	-106.41902	1105
WY0052407	16	CBM	Antelope CBM Project	44.96139	-106.38945	1104
WY0052407	18	CBM	Antelope CBM Project	44.95197	-106.38403	1104
WY0052407	22	CBM	Antelope CBM Project	44.98749	-106.49334	1106
WY0052407	31	CBM	Antelope CBM Project	44.97180	-106.49783	1106
WY0052407	33	CBM	Antelope CBM Project	44.95533	-106.44515	1105
WY0052485	1	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95930	-106.77800	3002
WY0052485	2	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95670	-106.78200	3002
WY0052485	3	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95570	-106.78380	3002
WY0052485	4	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95370	-106.77610	3002
WY0052485	5	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95200	-106.77160	3002
WY0052485	6	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.95060	-106.75770	3002
WY0052485	7	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.94830	-106.76620	3002
WY0052485	8	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.94310	-106.76700	3002
WY0052485	9	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.94120	-106.76720	3002
WY0052485	10	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.94080	-106.76150	3002
WY0052485	11	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.93330	-106.76100	3002
WY0052485	12	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.89160	-106.74330	3002
WY0052485	13	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.89000	-106.73960	3002
WY0052485	14	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.88890	-106.71390	3002
WY0052485	15	CBM	Rucki 15 POD Non-Discharging Reservoirs	44.88180	-106.72770	3002
WY0052671	1	CBM	Farmland 26 Option 2	44.80622	-106.79895	3010
WY0052671	2	CBM	Farmland 26 Option 2	44.81632	-106.79542	3010
WY0052671	3	CBM	Farmland 26 Option 2	44.80267	-106.79486	3010
WY0052671	4	CBM	Farmland 26 Option 2	44.80135	-106.79985	3010
WY0052671	5	CBM	Farmland 26 Option 2	44.79248	-106.80231	3010
WY0052671	6	CBM	Farmland 26 Option 2	44.78227	-106.79958	3010
WY0052671	7	CBM	Farmland 26 Option 2	44.80880	-106.81880	3010
WY0052671	8	CBM	Farmland 26 Option 2	44.80793	-106.82113	3010

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0052671	9	CBM	Farmland 26 Option 2	44.78512	-106.82369	3010
WY0052671	10	CBM	Farmland 26 Option 2	44.77744	-106.81891	3008
WY0052671	11	CBM	Farmland 26 Option 2	44.77126	-106.82898	3008
WY0052671	12	CBM	Farmland 26 Option 2	44.76819	-106.82159	3008
WY0052671	13	CBM	Farmland 26 Option 2	44.80882	-106.83139	3010
WY0052671	14	CBM	Farmland 26 Option 2	44.81065	-106.83520	3010
WY0052671	15	CBM	Farmland 26 Option 2	44.81348	-106.83696	3010
WY0052671	16	CBM	Farmland 26 Option 2	44.80991	-106.83764	3010
WY0052671	17	CBM	Farmland 26 Option 2	44.80825	-106.84055	3008
WY0052671	18	CBM	Farmland 26 Option 2	44.80626	-106.84900	3008
WY0052671	19	CBM	Farmland 26 Option 2	44.81223	-106.84925	3008
WY0053112	1	CBM	Ash Creek Option 1A	44.94886	-106.81985	3007
WY0053112	2	CBM	Ash Creek Option 1A	44.96698	-106.93676	3019
WY0053112	3	CBM	Ash Creek Option 1A	44.96695	-106.94087	3019
WY0053112	4	CBM	Ash Creek Option 1A	44.95425	-106.88892	3017
WY0053112	5	CBM	Ash Creek Option 1A	44.95732	-106.88512	3017
WY0053112	6	CBM	Ash Creek Option 1A	44.97084	-106.88585	3017
WY0053112	7	CBM	Ash Creek Option 1A	44.97694	-106.88519	3017
WY0053112	8	CBM	Ash Creek Option 1A	44.94143	-106.91880	3019
WY0053112	9	CBM	Ash Creek Option 1A	44.93923	-106.83332	3007
WY0053121	1	CBM	Perry Ranch Option 1A	44.88688	-106.83700	3007
WY0053121	2	CBM	Perry Ranch Option 1A	44.88709	-106.83457	3007
WY0053121	3	CBM	Perry Ranch Option 1A	44.87906	-106.83052	3007
WY0053139	1	CBM	Brinkerhoff Option 1A	44.94740	-106.81460	3007
WY0053317	1	CBM	Peterson 29 POD Off-Channel Facilities	44.97290	-106.76740	3002
WY0053317	2	CBM	Peterson 29 POD Off-Channel Facilities	44.96260	-106.77520	3002
WY0053325	1	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.98460	-106.77830	3002
WY0053325	2	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.97710	-106.76960	3002
WY0053325	3	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.97910	-106.77160	3002
WY0053325	4	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.97790	-106.77500	3002
WY0053325	5	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.97030	-106.76710	3002
WY0053325	6	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.97350	-106.77330	3002
WY0053325	7	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96840	-106.76690	3002
WY0053325	8	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96930	-106.77180	3002
WY0053325	9	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96530	-106.78250	3002
WY0053325	10	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96280	-106.78070	3002
WY0053325	11	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96430	-106.77970	3002
WY0053325	12	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96020	-106.77870	3002
WY0053325	13	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96010	-106.77700	3002
WY0053325	14	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96180	-106.76770	3002
WY0053325	15	CBM	Peterson 29 POD Non-Discharging Reservoirs	44.96580	-106.76470	3002
WY0053422	1	CBM	Brinkerhoff 6 Option 1A	44.94060	-106.78880	3007
WY0053422	2	CBM	Brinkerhoff 6 Option 1A	44.92956	-106.79803	3007
WY0053422	3	CBM	Brinkerhoff 6 Option 1A	44.93590	-106.78100	3007
WY0053431	1	CBM	Brinkerhoff 17 & 19 Non-Discharging Option 2	44.91518	-106.77356	3007
WY0053431	2	CBM	Brinkerhoff 17 & 19 Non-Discharging Option 2	44.91597	-106.76541	3007
WY0053431	3	CBM	Brinkerhoff 17 & 19 Non-Discharging Option 2	44.89181	-106.75918	3007

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0053449	1	CBM	Brinkerhoff 23 Option 1A	44.89660	-106.83090	3007
WY0053449	2	CBM	Brinkerhoff 23 Option 1A	44.89400	-106.83000	3007
WY0053520	1	CBM	AC Ranch North & East Hank Reservoir	44.88859	-106.86560	3007
WY0053589	1	CBM	Little Badger Creek Option 1A	44.97970	-106.78873	3002
WY0053686	1	CBM	Pipeline Ridge POD Off-Channel	44.77870	-106.73470	3012
WY0053686	2	CBM	Pipeline Ridge POD Off-Channel	44.76930	-106.73010	3012
WY0053686	3	CBM	Pipeline Ridge POD Off-Channel	44.77570	-106.72260	3012
WY0053686	4	CBM	Pipeline Ridge POD Off-Channel	44.77100	-106.72480	3012
WY0053708	1	CBM	AC Ranch North & East Option 1A	44.84817	-106.83902	3010
WY0053708	2	CBM	AC Ranch North & East Option 1A	44.84545	-106.84591	3008
WY0053708	3	CBM	AC Ranch North & East Option 1A	44.84279	-106.84818	3008
WY0053708	4	CBM	AC Ranch North & East Option 1A	44.84094	-106.84906	3008
WY0053708	5	CBM	AC Ranch North & East Option 1A	44.83984	-106.84363	3010
WY0053708	6	CBM	AC Ranch North & East Option 1A	44.84635	-106.83638	3010
WY0053881	1	CBM	AC Ranch Central Option 1A	44.81490	-106.88510	3008
WY0053881	2	CBM	AC Ranch Central Option 1A	44.81194	-106.86583	3008
WY0053881	3	CBM	AC Ranch Central Option 1A	44.81045	-106.86998	3008
WY0053881	4	CBM	AC Ranch Central Option 1A	44.80896	-106.87124	3008
WY0053881	5	CBM	AC Ranch Central Option 1A	44.80334	-106.88354	3008
WY0053881	6	CBM	AC Ranch Central Option 1A	44.80232	-106.86845	3008
WY0053881	7	CBM	AC Ranch Central Option 1A	44.78867	-106.85790	3008
WY0053881	8	CBM	AC Ranch Central Option 1A	44.77856	-106.84174	3008
WYG310005	1	CBM	Dewey, Pilch, LPD Ranch Leases	44.96995	-106.86232	3007
WYG310005	2	CBM	Dewey, Pilch, LPD Ranch Leases	44.96995	-106.86232	3007
WYG310005	3	CBM	Dewey, Pilch, LPD Ranch Leases	44.96995	-106.86232	3007
WYG310005	4	CBM	Dewey, Pilch, LPD Ranch Leases	44.96995	-106.86232	3007
WYG390028	1	CBM	Ash Creek	44.94886	-106.81985	3007
WYG390028	2	CBM	Ash Creek	44.96698	-106.93676	3019
WYG390028	3	CBM	Ash Creek	44.96695	-106.94087	3019
WYG390028	4	CBM	Ash Creek	44.95425	-106.88892	3017
WYG390028	5	CBM	Ash Creek	44.95732	-106.88512	3017
WYG390028	6	CBM	Ash Creek	44.97084	-106.88585	3017
WYG390028	7	CBM	Ash Creek	44.97694	-106.88519	3017
WYG390028	8	CBM	Ash Creek	44.94143	-106.91880	3019
WYG390028	9	CBM	Ash Creek	44.93923	-106.83332	3007
WYG390029	1	CBM	Burges State	44.83611	-106.73311	3007
WYG390029	2	CBM	Burges State	44.83429	-106.74708	3010
WYG390029	3	CBM	Burges State	44.83164	-106.74078	3010
WYG390029	4	CBM	Burges State	44.83039	-106.73164	3010
WYG390029	5	CBM	Burges State	44.82594	-106.73217	3010
WYG390029	6	CBM	Burges State	44.82678	-106.74233	3010
WYG390029	7	CBM	Burges State	44.82331	-106.74272	3010
WYG390029	8	CBM	Burges State	44.81661	-106.74956	3010
WYG390033	1	CBM	Cherni-Dow	44.89876	-106.90979	3019
WYG390033	2	CBM	Cherni-Dow	44.89600	-106.89771	3007
WYG390033	3	CBM	Cherni-Dow	44.91573	-106.90694	3019
WYG390033	4	CBM	Cherni-Dow	44.91180	-106.92678	3019

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WYG390033	5	CBM	Cherni-Dow	44.90972	-106.91339	3019
WYG390035	1	CBM	Flat Broke General Permit	44.84827	-106.90723	3008
WYG390035	2	CBM	Flat Broke General Permit	44.83693	-106.87513	3008
WYG390037	1	CBM	Brinkerhoff General Permit	44.94740	-106.81460	3007
WYG390038	1	CBM	Brinkerhoff 23 General Option 1A	44.89400	-106.83000	3007
WYG390038	2	CBM	Brinkerhoff 23 General Option 1A	44.89400	-106.83000	3007
WYG390039	1	CBM	Durcholtz Gen Option 1	44.93965	-106.84505	3007
WYG390040	1	CBM	Brinkerhoff 6 General Option 1A	44.94060	-106.78880	3007
WYG390040	2	CBM	Brinkerhoff 6 General Option 1A	44.94060	-106.78880	3007
WYG390040	3	CBM	Brinkerhoff 6 General Option 1A	44.94060	-106.78880	3007
WYG390041	1	CBM	Hutton Off-Channel CBM Facility	44.84750	-106.90330	3008
WYG390041	2	CBM	Hutton Off-Channel CBM Facility	44.84540	-106.89880	3008
WYG390041	3	CBM	Hutton Off-Channel CBM Facility	44.82680	-106.92650	3008
WYG390041	4	CBM	Hutton Off-Channel CBM Facility	44.82730	-106.92910	3008
WYG390041	5	CBM	Hutton Off-Channel CBM Facility	44.81860	-106.92500	3008
WYG390041	6	CBM	Hutton Off-Channel CBM Facility	44.81640	-106.92970	3008
WYG390041	7	CBM	Hutton Off-Channel CBM Facility	44.81170	-106.92840	3008
WYG390041	8	CBM	Hutton Off-Channel CBM Facility	44.80890	-106.92460	3008
WYG390041	9	CBM	Hutton Off-Channel CBM Facility	44.83220	-106.91120	3008
WYG390041	10	CBM	Hutton Off-Channel CBM Facility	44.83880	-106.92010	3008
WYG390045	1	CBM	Perry Ranch General Permit	44.88688	-106.83700	3007
WYG390045	2	CBM	Perry Ranch General Permit	44.88709	-106.83457	3007
WYG390045	3	CBM	Perry Ranch General Permit	44.87906	-106.83052	3007
WYG390056	1	CBM	Little Badger	44.97970	-106.78873	3002
MT0000892	7	Coal Mine	West Decker	45.07778	106.81500	3000
MT0024210	2	Coal Mine	East Decker	45.05194	106.79139	3000
MT0030457	1	CBM	Fidelity Tongue River Project	45.00459	-106.87188	3016
MT0030457	2	CBM	Fidelity Tongue River Project	44.99924	-106.87419	3016
MT0030457	3	CBM	Fidelity Tongue River Project	45.00027	-106.87293	3016
MT0030457	4	CBM	Fidelity Tongue River Project	45.00192	-106.86620	3016
MT0030457	5	CBM	Fidelity Tongue River Project	44.99835	-106.86620	3016
MT0030457	6	CBM	Fidelity Tongue River Project	45.00250	-106.85448	3016
MT0030457	7	CBM	Fidelity Tongue River Project	45.00406	-106.85263	3014
MT0030457	8	CBM	Fidelity Tongue River Project	44.99865	-106.87947	3016
MT0030457	9	CBM	Fidelity Tongue River Project	44.99609	-106.87980	3016
MT0030457	10	CBM	Fidelity Tongue River Project	45.00046	-106.86921	3016
MT0030457	11	CBM	Fidelity Tongue River Project	44.99634	-106.84768	3014
MT0030457	12	CBM	Fidelity Tongue River Project	44.99711	-106.82376	3006
MT0030457	13	CBM	Fidelity Tongue River Project	45.00264	-106.83066	3006
MT0030457	14	CBM	Fidelity Tongue River Project	44.99687	-106.84718	3014
MT0030457	15	CBM	Fidelity Tongue River Project	44.99736	106.82264	3006
MT0030457	16	CBM	Fidelity Tongue River Project	45.01280	-106.81879	3005
MT0030660	1	CBM	Pinnacle CBM	45.14583	106.75777	1112
MT0030724	1	CBM	Fidelity Treatment Facility	45.00495	106.82791	3006
WY0020435	1	Wastewater Treatment	Dayton Lagoon	44.88437	-107.2366	3077
WY0022161	1	Wastewater Treatment	Ranchester Lagoon	44.90805	-107.14074	3068

Permit	Outfall	Type	Name	Lat	Long	Subbasin
WY0026441	1	Wastewater Treatment	Bighorn Mountain KOA Lagoon	44.87658	-106.98255	3022
WY0036251	1	Wastewater Treatment	Powder Horn Ranch WWTP	44.70254	-106.97088	3028
WY0020010	1	Wastewater Treatment	City of Sheridan WWTP	44.82459	-106.96303	3022

A.5 References

City of Sheridan. 2006. City of Sheridan Wastewater Treatment. Available online at http://www.city-sheridan-wy.com/info/pwd-ud-wwt/index.php. Accessed December 12, 2006.

Committee on Interior and Insular Affairs. 1971. The Issues Related To Surface Mining A Summary Review, With Selected Readings. Committee on Interior and Insular Affairs. United States Senate 92nd Congress, 1st Session December 1971 Serial-No: Serial No. 92-10. Available online at http://www.osmre.gov/legishistory/publication92-10.htm (Accessed February 27, 2007).

Committee on Interior and Insular Affairs. 1977. Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs House of Representatives. January 10, 1977 to January 12, 1977; Serial No. 95-1. Available online at http://www.osmre.gov/legishistory/hearing011077.htm (Accessed February 27, 2007).

DOI. 1979. Interior Approves Spring Creek Surface Mine Plan in Montana [Online]. Department of Interior News Release Dated April 30, 1979. Available online at http://www.fws.gov/news/historic/1979/19790430b.pdf (Accessed October 20, 2006).

Gore, James A., and Lora S. Johnson. 1979. Observations on the Initial Biotic Recolonization of a Reclaimed Channel of the Tongue River in Wyoming. Wyoming Water Resources Series WRS-74. Available online at http://library.wrds.uwyo.edu/wrs/wrs-74/abstract.html (Accessed February 27, 2007).

Keith, Kristen, J. Bauder, and J. Wheaton. 2003. Frequently Asked Questions – Coal Bed Methane. Montana State University. Available online at http://waterquality.montana.edu/docs/methane/cbmfaq.shtml (accessed March 8, 2007).

Kiewit, 2006. Decker Coal Mine [Online]. Available at http://kiewit.com/markets/pro_decker.html.

Kiewit. 2007. Jobs Done Well [Online]. Available at http://www.kiewit.com/mining/reclamation.html (Accessed February 27, 2007).

MBOGC. 2005a. Montana Board of Oil and Gas Conservation Environmental Assessment For Pinnacle Gas Resources Inc Coal Creek Field Plan of Development (2005). Montana Board of Oil and Gas Conservation

MBOGC. 2005b. Montana Board of Oil and Gas Conservation – Finding of No Significant Impact and Notice of Decision – Pinnacle Gas Resources Inc. Coal Creek Field Plan of Development Project. Memo dated August 19, 2005.

MBOGC. 2006. Online Oil & Gas Information System – Coal Bed Methane [Online]. Montana Board of Oil and Gas Conservation. Available online at http://bogc.dnrc.state.mt.us/default.asp (Accessed December 8, 2006).

MDEQ. 1996. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Spring Creek Coal Company – Spring Creek Coal Mine [Permit #MT0024619]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2000. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Redstone Gas Partners, LLC [Permit #MT0030457]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2004. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Powder River Gas LLC Coal Creek Development Unit [Permit #MT0030660]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006a. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Decker Coal Company Decker West Mine [Permit #MT0000892]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006b. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Decker Coal Company Decker East Mine [Permit #MT0024210]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006c. MPDES Fact Sheet – Decker Coal Company Decker East Mine. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006d. MPDES Fact Sheet – Decker Coal Company Decker West Mine. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006e. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Fidelity Exploration and Production Company [Permit #MT0030457]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006f. Authorization to Discharge Under the Montana Pollutant Discharge Elimination System – Tongue River Project Water Treatment Facility [Permit #MT0030724]. Montana Department of Environmental Quality. Helena, Montana.

MDEQ. 2006g. Montana Abandoned Mines Inventory [GIS Computer File]. Montana Department of Environmental Quality. Helena, Montana. Available online at http://nris.mt.gov/gis/ (Accessed February 27, 2007).

Payne A., and Saffer, D.M. 2005. Surface water hydrology and shallow groundwater effects of coalbed methane development, upper Beaver drainage, Powder River Basin, WY. in Zoback, M.D. (Ed.). Wyoming State Geological Survey, Report of Investigations, v. 55.

Simonich. Mark A. 2000. Director. Montana Department of Environmental Quality. Letter to Bruce Williams (Redstone Gas Partners, LLC). Dated June 16, 2000.

USEPA. 2007. Permit Compliance System [Online] – NPDES Permit WY0020931. U.S. Environmental Protection Agency. Available online at http://www.epa.gov/enviro/html/pcs/. Accessed February 26, 2007.

WDEQ. 1988. Draft Application for the City of Sheridan WWTP – Permit #WY0020010. Wyoming Department of Environmental Quality Public Notice No. WY-88-007. Cheyenne, Wyoming.

WDEQ. 2003a. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Dayton Wastewater Treatment Lagoon [Permit #WY0020435]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2003b. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Big Horn Mountain KOA Sewage Plant [Permit #WY0026441]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2003c. Year 2003 Abandoned Mine Land Reclamation Award Nomination AML Project 8-II Sean Carroll and Goose Creek Spoils. Wyoming Department of Environmental Quality Abandoned Mine Land Program. Cheyenne, Wyoming. Available online at http://www.osmre.gov/awardsaml/wy03.pdf (Accessed February 27, 2007).

WDEQ. 2004. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Burgess Junction Dump Station [Permit # WY0020931]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2005a. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Sheridan Wastewater Treatment Plant [Permit #WY0020010]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2005b. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Ranchester Wastewater Treatment Lagoon [Permit #WY0022161]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2006a. NPDES Access Database for the Tongue River Watershed. Wyoming Department of Environmental Quality [Producer and Distributor]. Cheyenne, Wyoming. Obtained on November 22, 2006.

WDEQ. 2006b. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Powder Horn Ranch LLC [Permit #WY0036251]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2006c. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Conoco Phillips Sheridan Terminal [Permit # WY0030481]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2006d. Authorization to Discharge Under the National Pollutant Discharge Elimination System – Sheridan Water Treatment Plant [Permit # WY0001392]. Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2007. Online CBM Permits Database. Wyoming Department of Environmental Quality. Cheyenne, Wyoming. Available online at available at deq.state.wy.us/wqd/WYPDES_Permitting/ WYPDES_cbm/cbm.asp. Accessed February 26, 2007.

Wheaton, J. R, and Brown, T. H., 2005. Predicting changes in ground-water quality associated with coalbed methane infiltration ponds: in Western Resources Project Final Report-Produced Groundwater Associated with Coalbed Natural Gas Production in the Powder River Basin. Wyoming State Geological Survey Report of Investigation No. 55.

Williams, G. Bruce. 2000. Vice President Operations – Redstone Gas Partners, LLC. Letter to Tom Reid (Supervisor, Montana DEQ). Dated July 26, 2000.

WPCAC. 2005. Minutes from the Water Pollution Control Advisory Council (WPCAC) Meeting [Online]. July 5 2005 12:30 p.m. – 3:00 p.m. Director's Conference Room 111 Metcalf Building. Helena, Montana. Available online at http://www.deq.mt.gov/wqinfo/WPCAC/agendasMinutes/WPCAC070605.pdf (Accessed October 18, 2006).

WOGCC. 2007. Coal Bed Methane Wells by Drainage. Wyoming Oil and Gas Conservation Commission. Available online at http://wogcc.state.wy.us/crms.cfm (Accessed February 26, 2007).

WWDC. 2002. Powder/Tongue River Basin Plan. Wyoming Water Development Commission. Cheyenne, Wyoming. Available online at http://waterplan.state.wy.us/plan/powder/powder-plan.html (Accessed October 13, 2006).

Appendix B – LSPC Calibration Results

Table of Contents

Tables

Figures

B.1 Introduction

The Tongue River LSPC model was calibrated using flow and water quality data obtained from the U.S. Geological Survey's online National Water Information System (NWIS) database (available at http://waterdata.usgs.gov/nwis). All available NWIS data for the entire Tongue River watershed were downloaded and stored in a Microsoft Access database. Data from other agencies were not considered in the model calibration process.

The USGS data were evaluated for use in calibrating the Tongue River LSPC model. Ideal calibration sites had the following characteristics:

- Five or more years of continuous daily flow data, obtained between 1990 and 2006.
- Two or more years of calcium, magnesium, sodium, electrical conductivity (EC), and/or nutrient water quality data, collected at a quarterly frequency (or greater) between 1990 and 2006.
- Located at a spatial resolution to allow for calibration of varying watershed characteristics (e.g., topography, land use, soils, geology, precipitation, etc.).

Using these criteria, thirteen USGS monitoring sites were chosen to calibrate the Tongue River LSPC model. The sites are described in Table B-1 and shown in Figure B-1. Discharge and water chemistry were calibrated at eight of the sites, while five additional sites were used to help calibrate high-altitude snowmelt in the Bighorn Mountains only.

The following sections present the calibration results for each of the eight calibration sites, starting from upstream in the Tongue River and moving downstream to the mouth (Sections B.2 through B.6). Calibration results for Hanging Woman Creek (Section B.7), Otter Creek (Section B.8), and Pumpkin Creek (Section B.9) are then discussed, followed by the calibration of the high-altitude gages in the Bighorn Mountains (Sections B.10). Each section presents a summary of the available flow and water quality data for the site, followed by a comparison of the observed and modeled hydrology and water quality data. A brief discussion of the calibration results is also included.

Table B-1. USGS monitoring sites used for calibrating the Tongue River LSPC model.

Purpose	Location	USGS Site ID	LSPC Modeling Subbasin Number
Calibration of Discharge and Water Chemistry Throughout the Tongue River Watershed.	Tongue River near Dayton, Wyoming	06298000	3900
	Tongue River at the Montana-Wyoming State Line, Montana	06306300	3006
	Tongue River below the Tongue River Reservoir Dam	06307500	1112
	Tongue River near the Brandenberg Bridge, Montana	06307830	1047
	Tongue River at Miles City, Montana	06308500	1002
	Hanging Woman Creek near Birney, Montana	06307600	1095
	Otter Creek at Ashland, Montana	06307740	1059
	Pumpkin Creek near Miles City, Montana	06308400	1007
Calibration of High-altitude Snowmelt	Wolf Creek at Wolf, Wyoming	06299950	3070
	Big Goose Creek near Sheridan, Wyoming	06302000	3046
	Little Goose Creek near Bighorn, Wyoming	06303500	3029
	East Fork Big Goose Creek near Bighorn, Wyoming	06300500	3051
	Coney Creek above Twin Lakes near Bighorn, Wyoming	06301480	3060

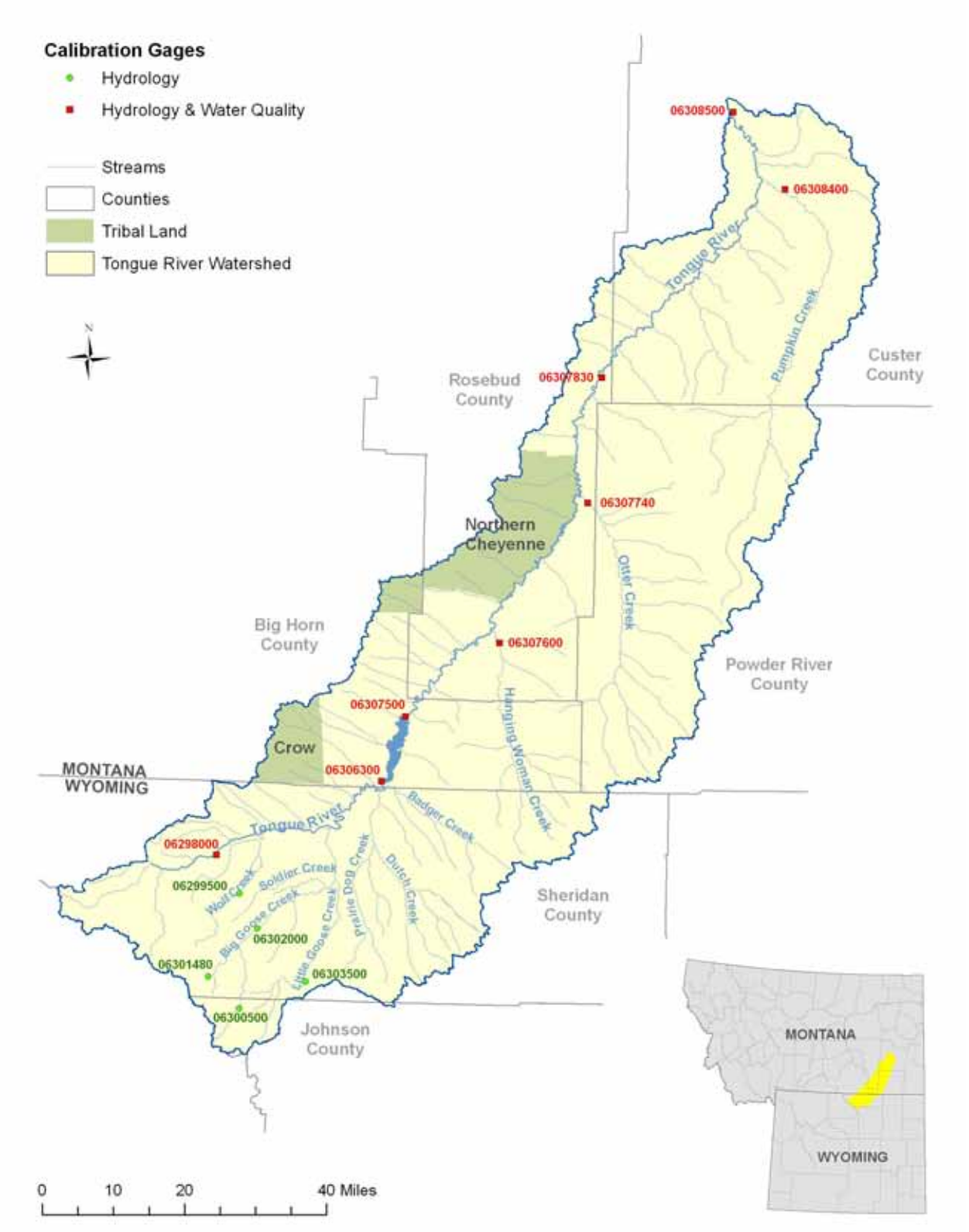

Figure B-1. Location of USGS monitoring sites used for calibrating the Tongue River LSPC model.

B.2 Tongue River near Dayton, Wyoming

The Tongue River at Dayton, Wyoming USGS gaging station (Gage ID 06298000) is located at latitude 44.84941º, longitude -107.30453º (NAD83) in Sheridan County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 4,060 feet (NGVD 29), and the gage has a watershed area of 206 square miles. No information was available regarding bankfull width or depth at this site. This gage corresponds to the LSPC modeling pour point for subbasin 3090. The location of the gage is shown in Figure B-1.

B.2.1 Hydrologic Calibration

Discharge data are available for the Tongue River near Dayton, Wyoming at USGS gage 06298000. The period of record at this gage for flow is from 1918 to 1929, and from October 1, 1940 to present. The record is 100 percent complete from October 1, 1940 to present. The 14-year period between October 1, 1992 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The limiting factor in running the LSPC model for USGS gage 06298000 was weather data. During model setup, the SNOTEL weather stations at Tie Creek, Burgess Junction, Sucker Creek, and Bone Springs only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1989 conditions.
- Three years are recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between October 1, 1992 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal, wet, and dry years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-2, Figure B-3, Figure B-4, Figure B-5, and Table B-2.

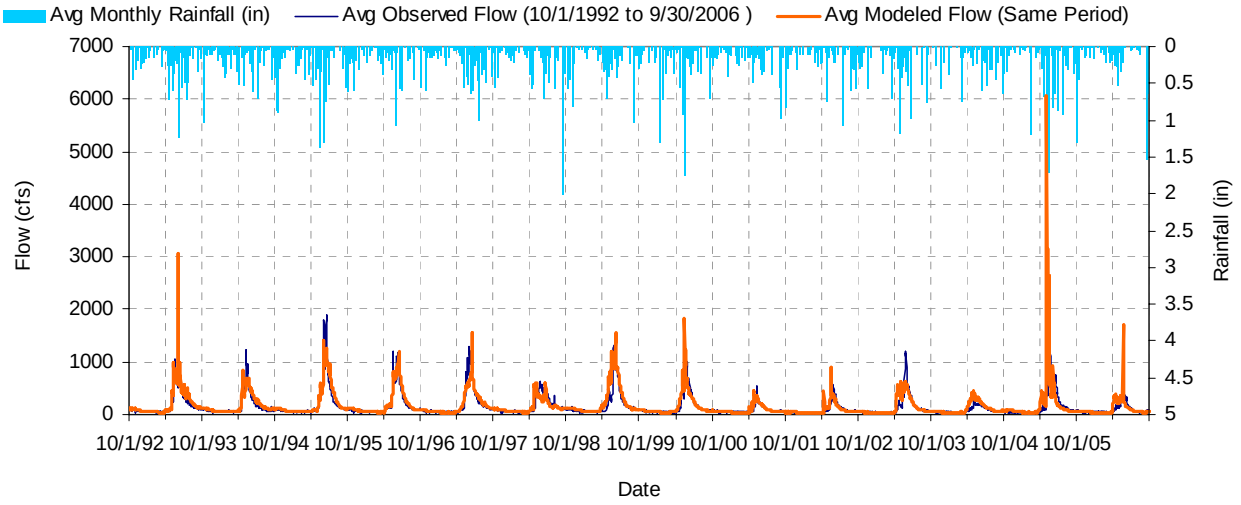

Figure B-2. Time series hydrologic calibration results (daily mean) for Tongue River at Dayton, Wyoming (Gage 06298000).

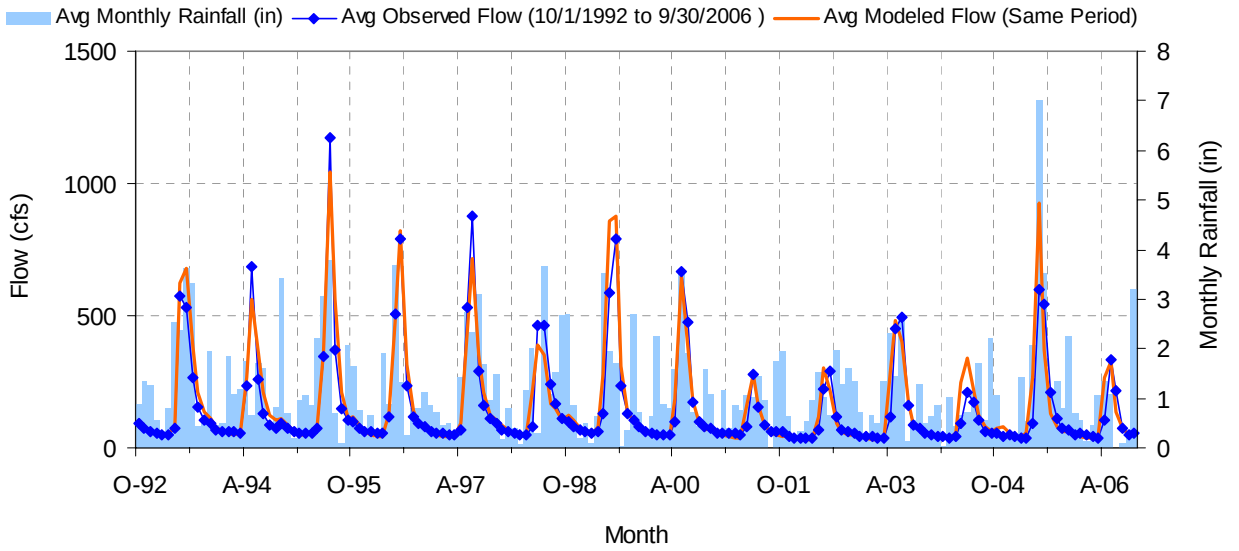

Figure B-3. Time series hydrologic calibration results (monthly mean) for Tongue River at Dayton, Wyoming (Gage 06298000).

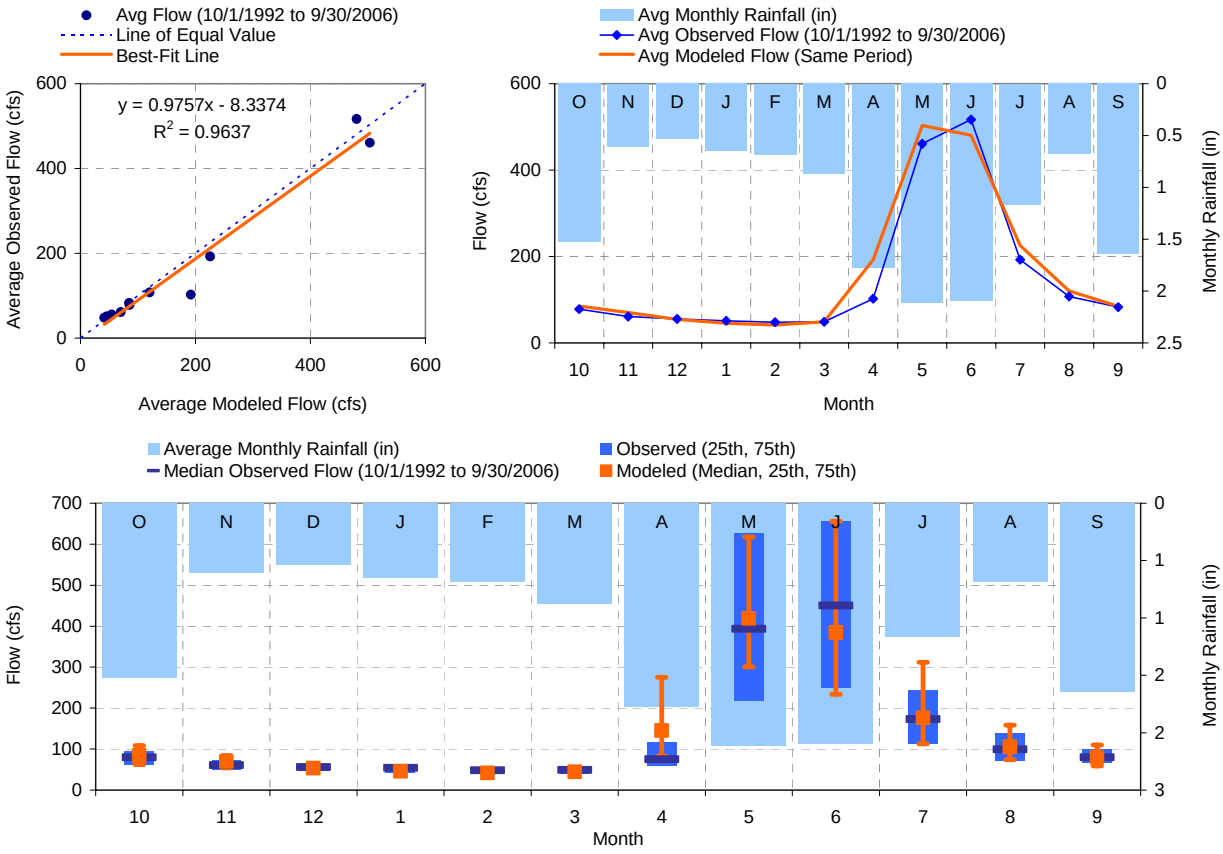

Figure B-4. Composite (average monthly) hydrologic calibration results for Tongue River at Dayton, Wyoming (October 1, 1992 to September 30, 2006).

Table B-2. Hydrologic calibration statistics for Tongue River near Dayton, Wyoming (USGS gage 06298000) (October 1, 1992 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	1,654,674	77	163	1,528,933	71	151	8.2%	8.1%	8.2%
Growing Season	1,477,365	117	217	1,348,782	100	198	9.5%	17.3%	9.5%
Non-growing Season	177,309	49	53	180,151	54	54	-1.6%	-9.3%	-1.6%
January	39,413	46	46	44,186	54	51	-10.8%	-15.6%	-10.8%
February	32,575	41	42	37,480	48	48	-13.1%	-13.5%	-13.1%
March	41,910	45	49	42,119	49	49	-0.5%	-9.0%	-0.5%
April	160,104	145	192	85,324	75	102	87.6%	93.4%	87.6%
May	433,352	419	503	396,621	393	461	9.3%	6.5%	9.3%
June	400,307	385	481	430,357	451	517	-7.0%	-14.6%	-7.0%
July	194,131	177	226	165,597	173	192	17.2%	2.1%	17.2%
August	103,601	106	120	92,559	100	108	11.9%	6.2%	11.9%
September	70,510	80	85	69,044	80	83	2.1%	-0.3%	2.1%
October	73,450	84	85	67,162	80	78	9.4%	5.5%	9.4%
November	58,509	70	70	50,850	61	61	15.1%	14.2%	15.1%
December	46,812	54	54	47,635	56	55	-1.7%	-4.2%	-1.7%
10% Highest Flows	1,618,334	87	177	1,489,030	79	164	8.7%	10.6%	8.0%
10% Lowest Flows	36,340	37	36	39,903	38	37	-8.9%	-3.3%	-3.9%

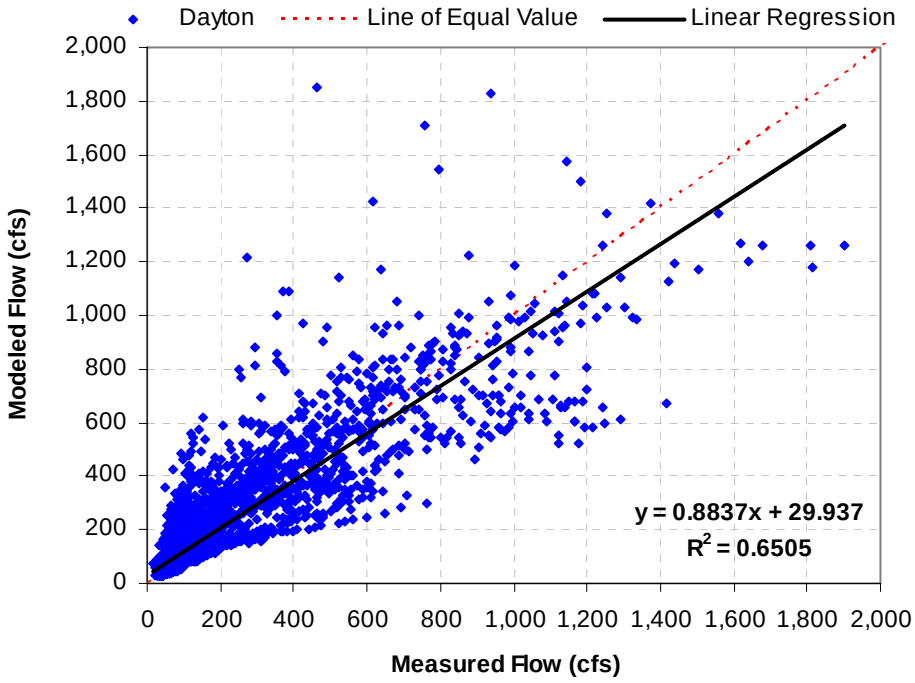

Figure B-5. Observed versus simulated scatter plot of average daily values for the Tongue River at Dayton, Wyoming (October 1, 1992 to September 30, 2006).

B.2.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), sodium (Na), total nitrogen (TN), and total phosphorus (TP) were modeled in the Tongue River to supplement the water quality impairment analysis for salinity, sodium adsorption ratio (SAR), and nutrients (as described in the Assessment Report). Data were collected at USGS Gage 06298000 (Tongue River near Dayton, Wyoming) at varying frequencies from October 10, 1966 to September 24, 1981; and from January 14, 1999 to August 14, 2002. No continuous data are available for this gage, only grab samples. The entire period between January 1, 1999 and August 31, 2002 was chosen for water quality calibration, as the model could not be run for years prior to 1990 due to limited weather data, and no monitoring data were available after 2002. The following sections present a parameter-by-parameter discussion of the water quality calibration for the Tongue River near Dayton, Wyoming.

B.2.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for the Tongue River near Dayton, Wyoming at USGS gage 06298000. The period of record at this gage for salinity is October 10, 1966 to September 24, 1981; and from January 14, 1999 to August 14, 2002. The period between January 1999 and August 2002 was chosen for water quality calibration because it had the most recent data. The observed and simulated salinity values for the calibration period at this gage are shown in Figure B-6 and Figure B-7.

Due to the limited observed data (n=40), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating SC was a visual inspection of modeled and observed data.

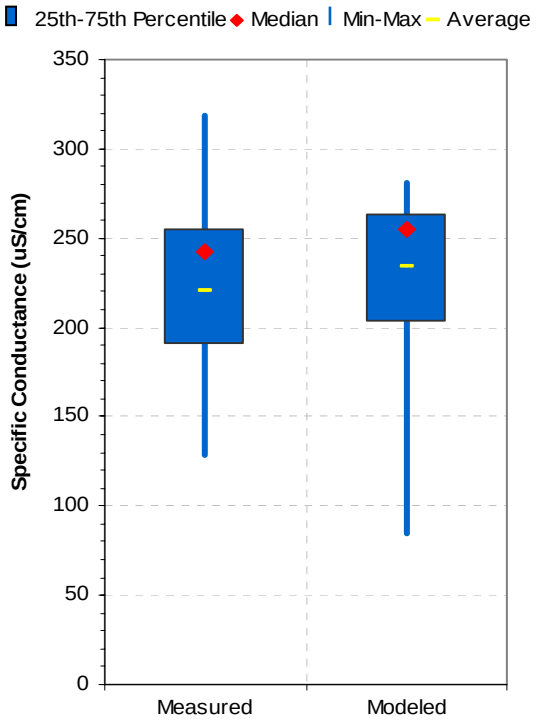

Figure B-6. Modeled and observed salinity data for the Tongue River at Dayton, Wyoming (January 1, 1999 to August 31, 2002).

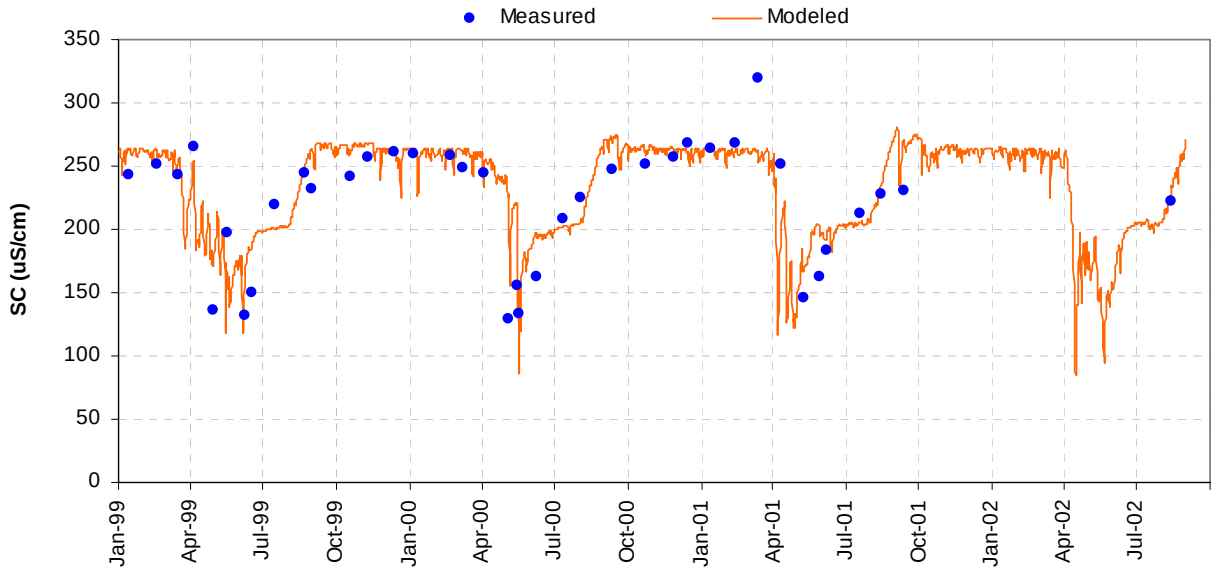

Figure B-7. Time series of salinity data for the Tongue River at Dayton, Wyoming (USGS gage 06298000).

B.2.2.2 SAR

SAR values were computed for the Tongue River at USGS gage 06298000 where calcium, magnesium, and sodium were collected on the same day. The period of record at this gage for SAR is October 10, 1966 to September 24, 1981; and from January 14, 1999 to August 14, 2002. The period between January 1999 and August 2002 was chosen for water quality calibration. The observed and simulated SAR values for the calibration period at this gage are shown in Figure B-8 and Figure B-9.

Due to the limited observed data (n=39), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating SAR was a visual inspection of modeled and observed data.

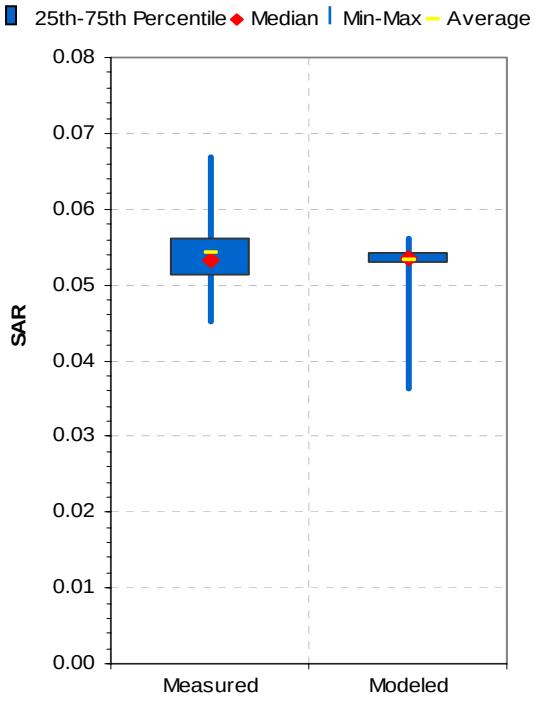

Figure B-8. Modeled and observed SAR data for the Tongue River at Dayton, Wyoming (January 14, 1999 to August 31, 2002).

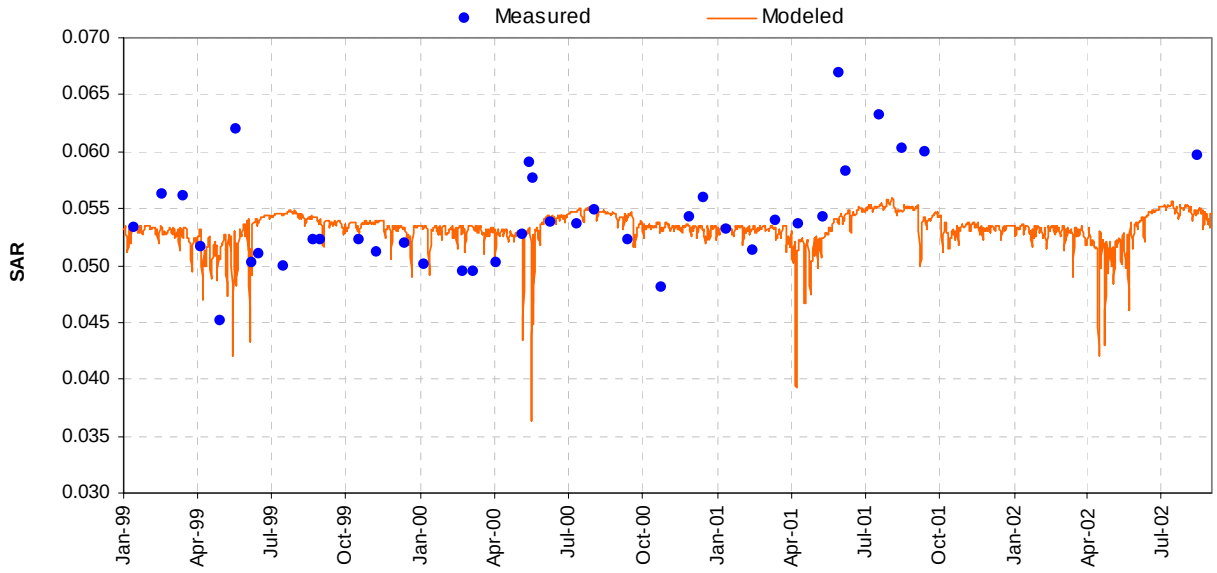

Figure B-9. Time series of SAR data for the Tongue River at Dayton, Wyoming (USGS gage 06298000).

B.2.2.3 Total Phosphorus (TP)

TP data are available for the Tongue River near Dayton, Wyoming at USGS gage 06298000. The period of record at this gage for TP is April 3, 1974 to June 28, 1988; and from October 6, 1999 to September 14, 2002. The period between October 1, 1999 and September 30, 2002 was chosen for water quality calibration because this period had the most recent frequently collected data. The observed and simulated TP concentrations for the calibration period at this gage are shown in Figure B-10 and Figure B-11.

Due to the limited observed data (n=27), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating TP was a visual inspection of modeled and observed data.

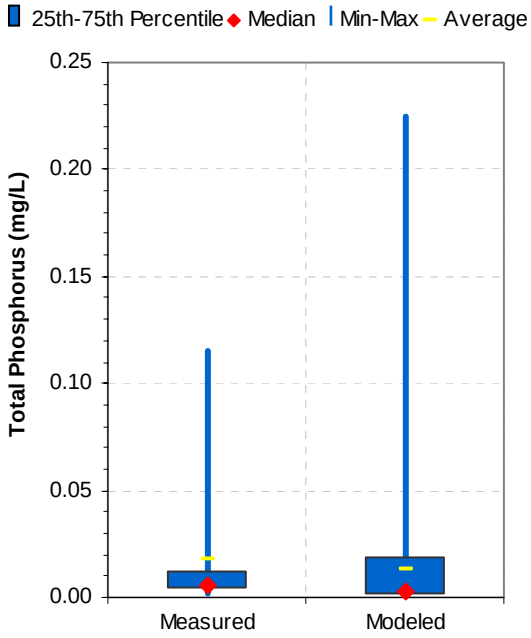

Figure B-10. Modeled and observed TP data for the Tongue River at Dayton, Wyoming (October 1, 1999 to September 30, 2002).

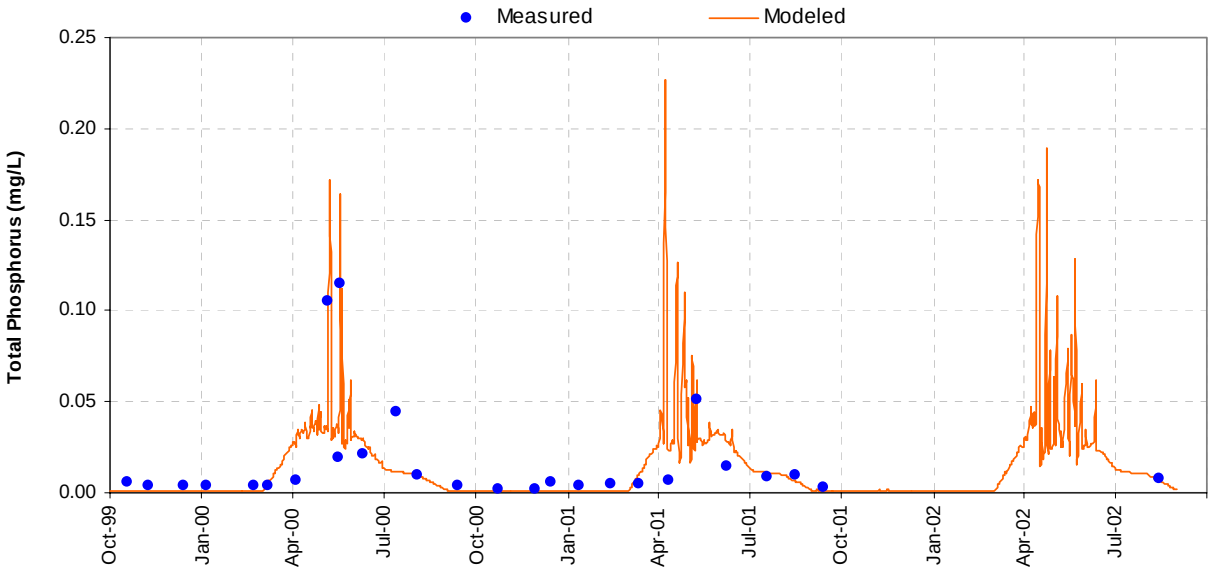

Figure B-11. Time series of TP data for the Tongue River at Dayton, Wyoming (USGS gage 06298000).

B.2.2.4 Total Nitrogen (TN)

No total nitrogen data were available for the Tongue River at Dayton, Wyoming.

B.2.2.5 Water Temperature

Temperature data are available for the Tongue River near Dayton, Wyoming at USGS gage 06298000. The period of record at this gage for temperature is October 10, 1966 to June 28, 1988; and from September 23, 1998 to August 14, 2002. The period between October 1, 1998 and August 31, 2002 was chosen for water quality calibration because this period had the most recent frequently collected data. The observed and simulated temperatures for the calibration period at this gage are shown in Figure B-12 and Figure B-13.

Due to the limited observed data (n=39), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating temperature was a visual inspection of modeled and observed data.

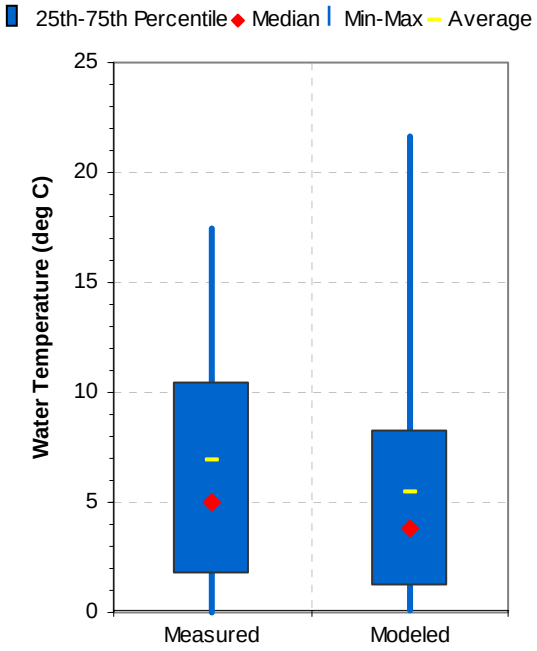

Figure B-12. Modeled and observed water temperature data for the Tongue River at Dayton, Wyoming (October 1, 1998 to August 31, 2002).

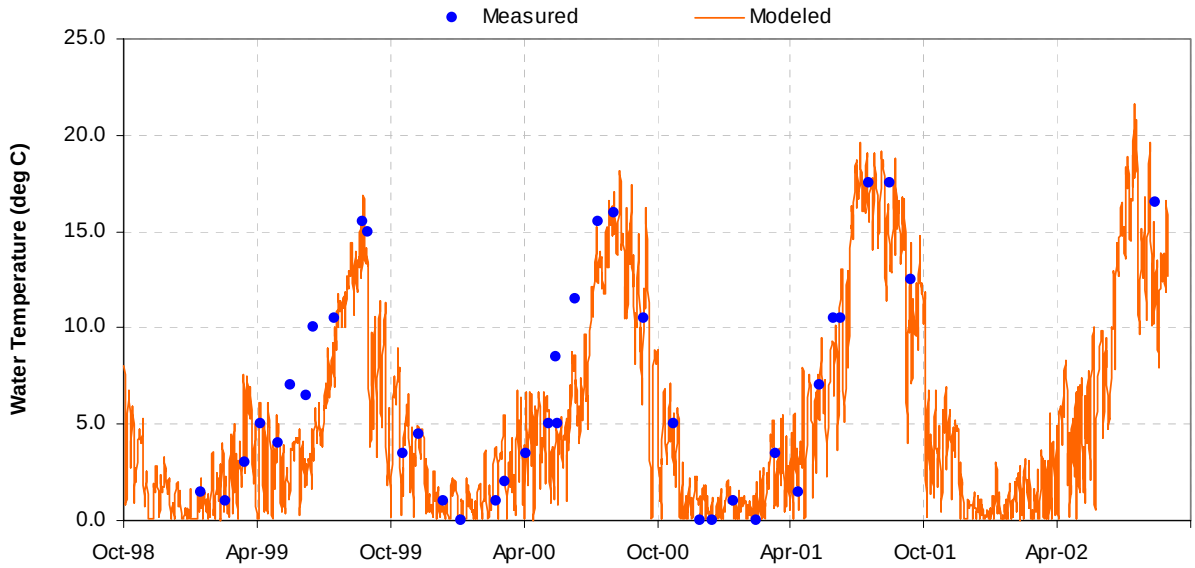

Figure B-13. Time series of water temperature data for the Tongue River at Dayton, Wyoming (USGS gage 06298000).

B.3 Tongue River at State Line near Decker, Montana

The Tongue River at State Line, near Decker, Montana USGS gaging station (Gage ID 06306300) is located at latitude 45.00886º, longitude -106.83618º (NAD83) in Big Horn County, Montana, Hydrologic Unit 10090101 (USGS, 2004). The gage elevation is 3,429 feet (NGVD 29), and the gage has a watershed area of 1,453 square miles. USGS reports a bankfull width of 140 feet and a mean bankfull depth of 4.0 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 3006. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-14.

Figure B-14. Tongue River at USGS Gage Tongue River at the State Line near Decker, Montana (06306300). Photos by USGS.

B.3.1 Hydrologic Calibration

Discharge data are available for the Tongue River at State Line near Decker, Montana at USGS gage 06306300. The period of record at this gage for discharge is July 8, 1960 to present and the record is 100 percent complete. The ten-year period between October 1, 1992 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The limiting factor in running the LSPC model for USGS gage 06306300 was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post 1989 conditions.
- Three years are recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between October 1, 1992 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal, wet, and dry years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-15, Figure B-16, Figure B-17, Figure B-18, and Table B-3.

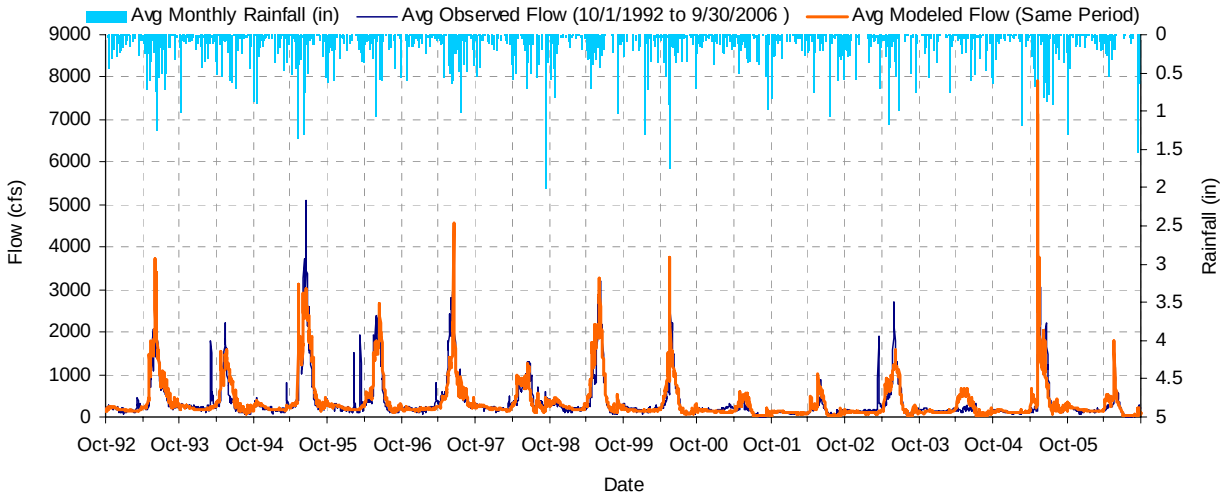

Figure B-15. Time series of hydrologic calibration results (daily mean) for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

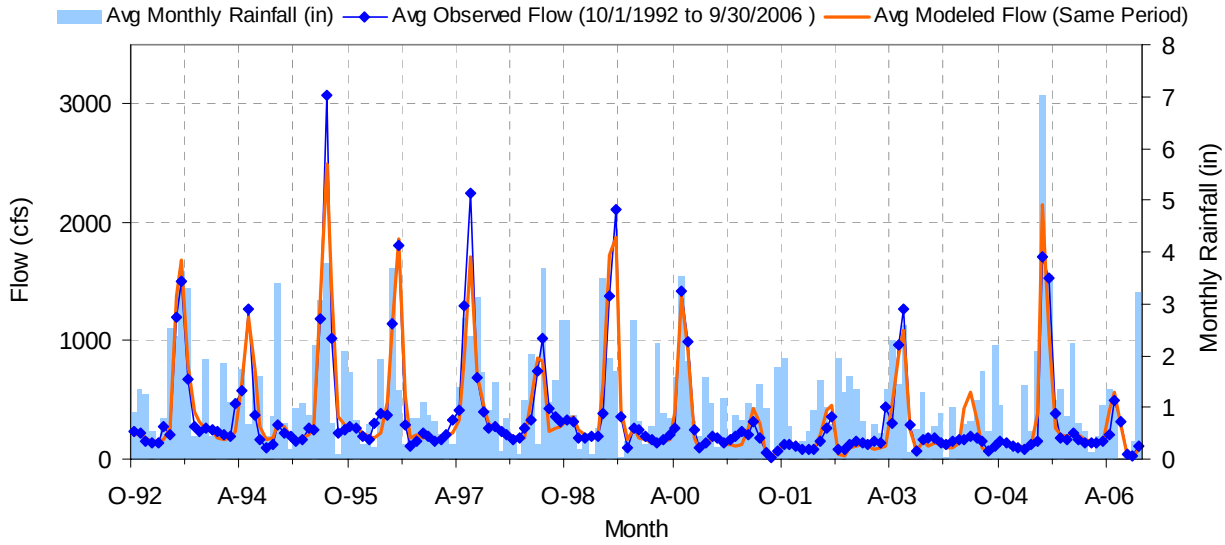

Figure B-16. Time series of hydrologic calibration results (monthly mean) for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

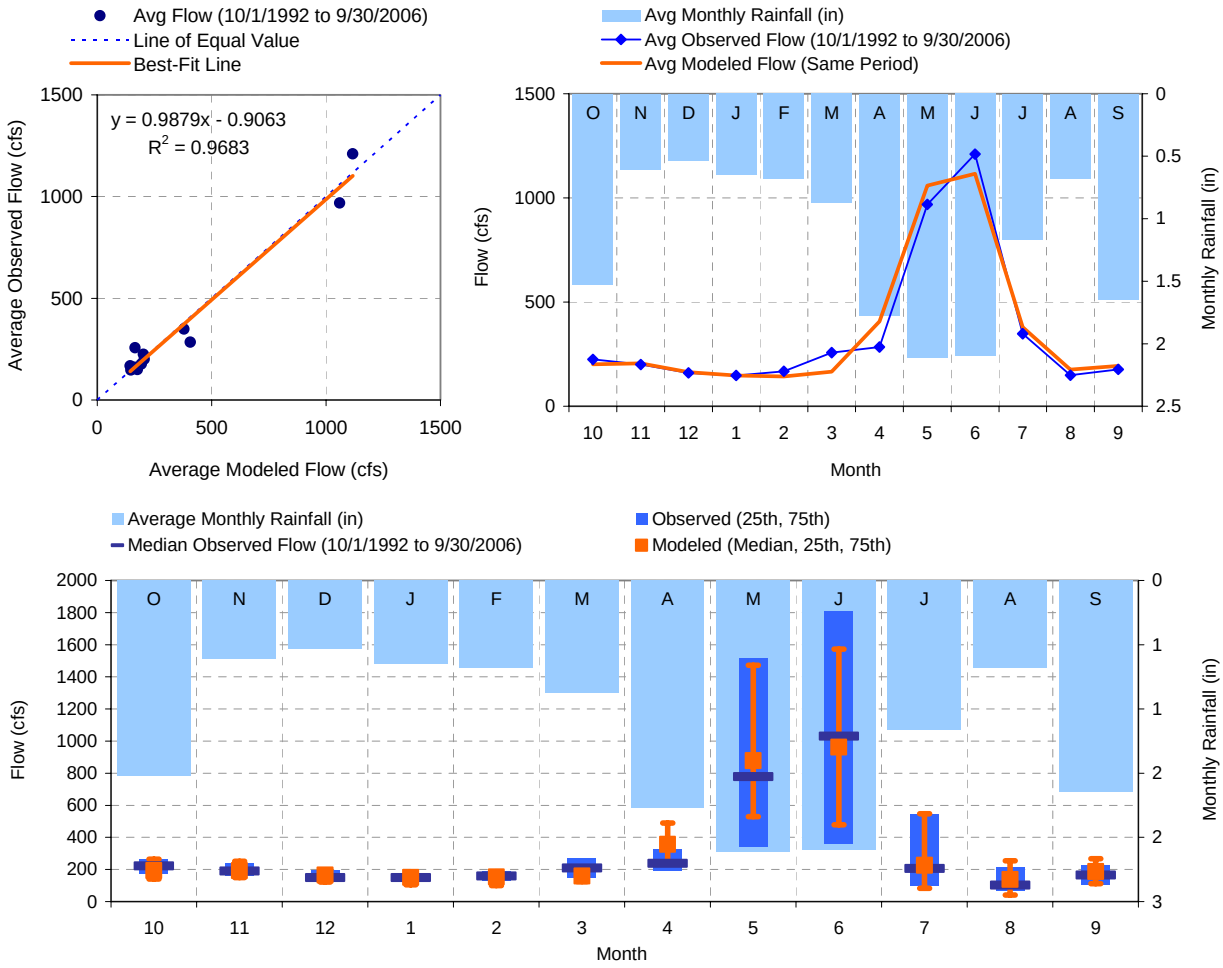

Figure B-17. Composite (average monthly) hydrologic calibration results for the Tongue River at State Line near Decker, Montana (USGS Gage 06306300) (October 1, 1992 to September 30, 2006).

Table B-3. Hydrologic Calibration Statistics for Tongue River at State Line, USGS Gage 06306300 (October 1, 1992 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	3,686,117	193	363	3,630,818	196	358	1.5%	-1.8%	1.5%
Growing Season	3,135,028	251	461	3,068,669	230	451	2.2%	9.3%	2.2%
Non-growing Season	551,089	163	165	562,149	160	168	-2.0%	2.0%	-2.0%
January	126,937	152	147	126,635	150	147	0.2%	1.1%	0.2%
February	112,458	153	144	131,086	160	167	-14.2%	-4.1%	-14.2%
March	142,389	160	165	221,028	209	257	-35.6%	-23.2%	-35.6%
April	338,853	357	407	236,941	238	284	43.0%	49.9%	43.0%
May	912,335	878	1,060	833,895	778	969	9.4%	12.9%	9.4%
June	929,960	962	1,116	1,008,163	1,030	1,210	-7.8%	-6.6%	-7.8%
July	326,131	227	379	299,897	207	348	8.7%	9.7%	8.7%
August	151,244	138	176	128,267	103	149	17.9%	34.2%	17.9%
September	160,766	187	193	147,385	166	177	9.1%	13.2%	9.1%
October	173,351	193	201	193,093	222	224	-10.2%	-12.8%	-10.2%
November	171,516	192	206	166,762	190	200	2.9%	1.2%	2.9%
December	140,178	165	163	137,667	150	160	1.8%	10.0%	1.8%
10% Highest Flows	3,630,095	209	398	3,563,679	209	391	1.9%	-0.2%	1.6%
10% Lowest Flows	56,022	54	55	67,140	74	65	-16.6%	-27.4%	-14.8%

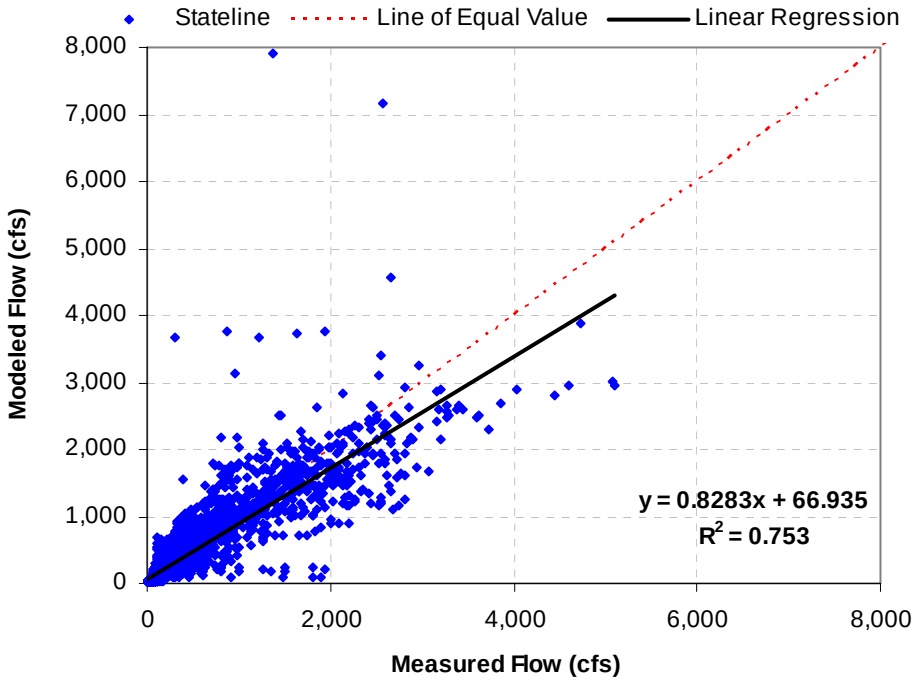

Figure B-18. Observed versus simulated scatter plot of average daily values for the Tongue River at State Line, Montana (October 1, 1992 to September 30, 2006).

B.3.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), sodium (Na), total nitrogen (TN), and total phosphorus (TP) were modeled in the Tongue River to supplement the water quality impairment analysis for salinity, sodium adsorption ration (SAR), and nutrients. Data were collected at USGS Gage 06306300 (Tongue River at the Montana-Wyoming State Line) at varying frequencies from October 1, 1982 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration for the Tongue River at the Montana-Wyoming State Line.

B.3.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for the Tongue River at State Line near Decker, Montana at USGS gage 06306300. The period of record at this gage for salinity is October 1, 1982 to present. During this period, samples were collected at varying frequencies. Daily data were collected from October 1, 1982 to December 31, 1986, and from August 21, 2000 to present. The daily data collected between October 1, 2000 and September 30, 2006 were used for the salinity calibration. This data provided 6 years of nearly continuous SC data with which to calibrate the LSPC model (n = 1914, 89 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-19, Figure B-20, Figure B-21, Figure B-22, Figure B-23, and Table B-4.

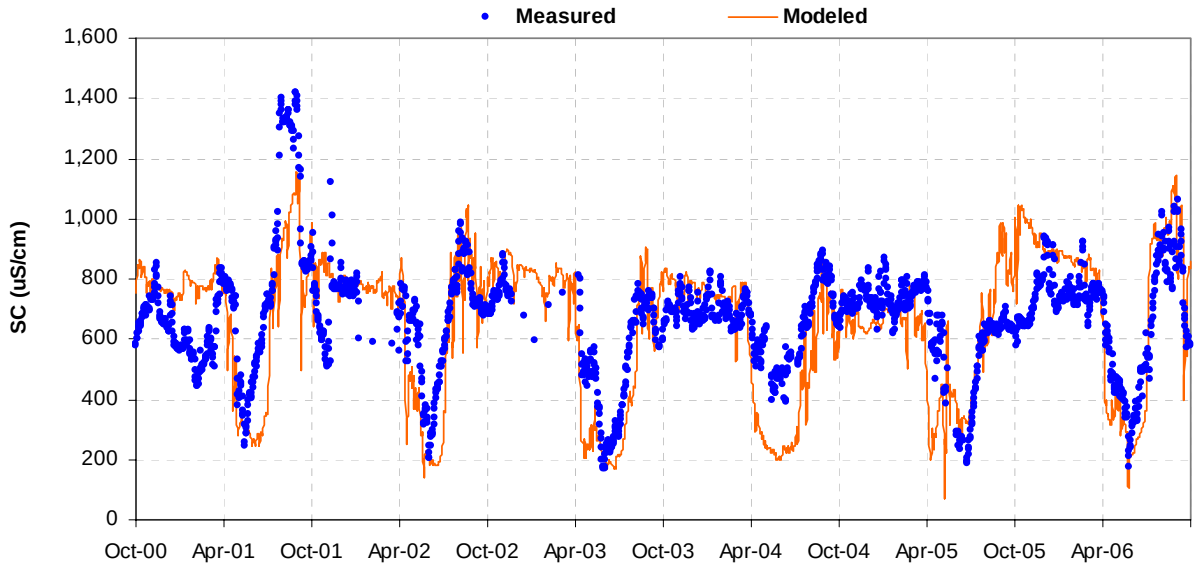

Figure B-19. Time series of continuous salinity data for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

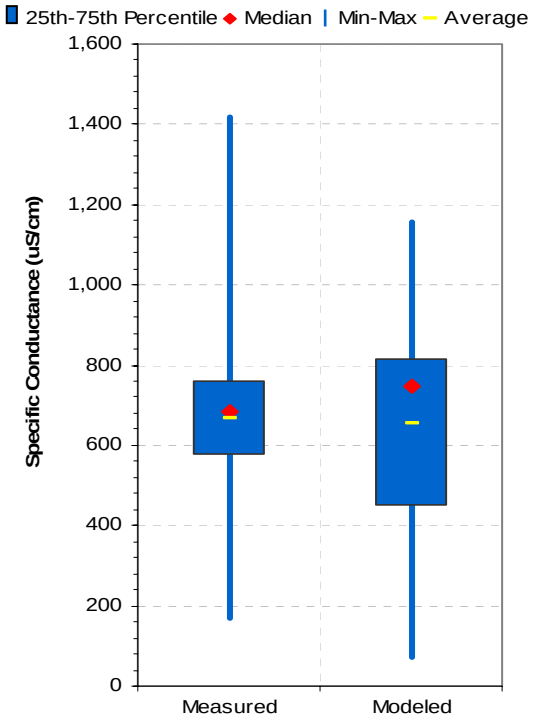

Figure B-20. Distribution of measured and modeled salinity data for the Tongue River at State Line near Decker, Montana (October 1, 2000 to September 30, 2006).

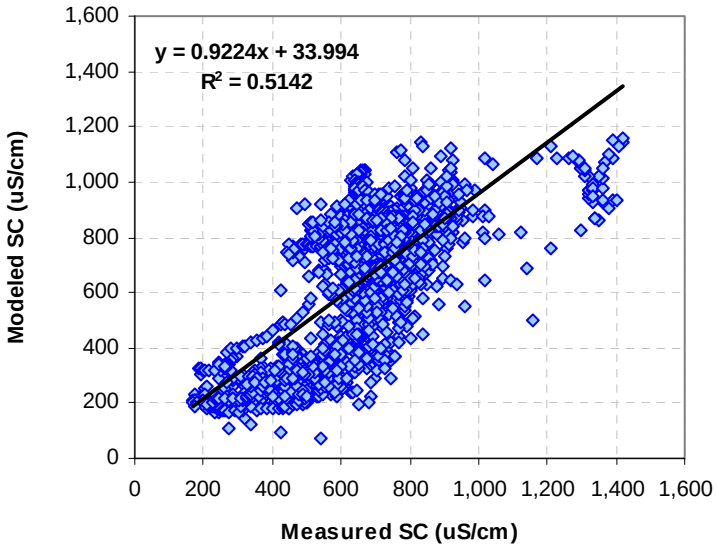

Figure B-21. Observed versus simulated scatter plot of average daily SC values for the Tongue River at State Line, Montana (October 1, 2000 to September 30, 2006).

Table B-4. Salinity calibration statistics for Tongue River at State Line near Decker, Montana (USGS Gage 06306300) (October 1, 2000 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)
All Data	737	647	686	667	7.4%	-2.9%
Growing Season	643	593	658	648	-2.3%	-8.4%
Non-growing Season	770	777	723	712	6.4%	9.1%
January	755	777	716	693	5.5%	12.0%
February	765	758	711	674	7.7%	12.4%
March	770	744	748	721	2.9%	3.1%
April	366	417	618	629	-40.8%	-33.6%
May	283	284	428	437	-33.9%	-34.9%
June	239	249	380	392	-37.1%	-36.7%
July	569	588	635	651	-10.4%	-9.6%
August	858	827	819	873	4.8%	-5.3%
September	764	776	718	758	6.5%	2.4%
October	815	820	690	688	18.2%	19.3%
November	788	797	750	740	5.1%	7.7%
December	767	768	717	723	7.0%	6.2%

[1]**Observed data consist of daily SC data collected in the Tongue River at the State Line (USGS Gage 06306300). Months with less than 15 observed samples were excluded from this analysis.**

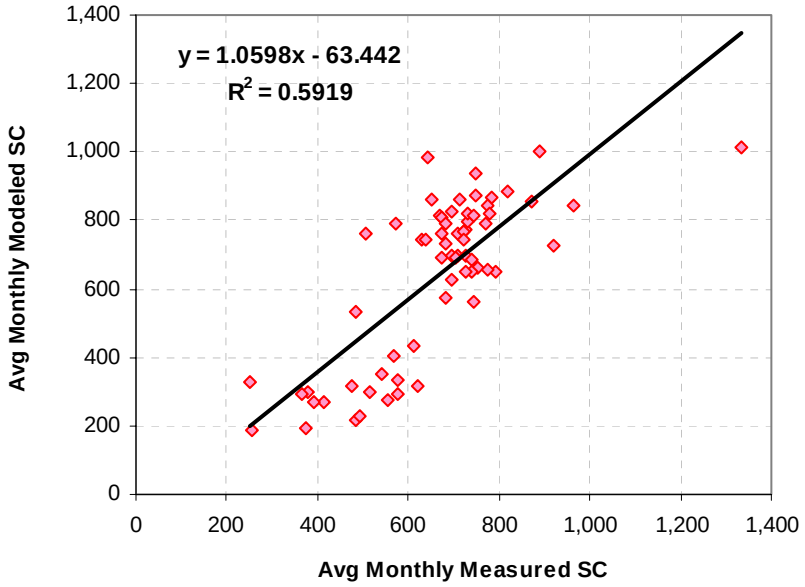

Figure B-22. Observed versus simulated scatter plot of average monthly SC values for the Tongue River at State Line, Montana (October 1, 2000 to September 30, 2006).

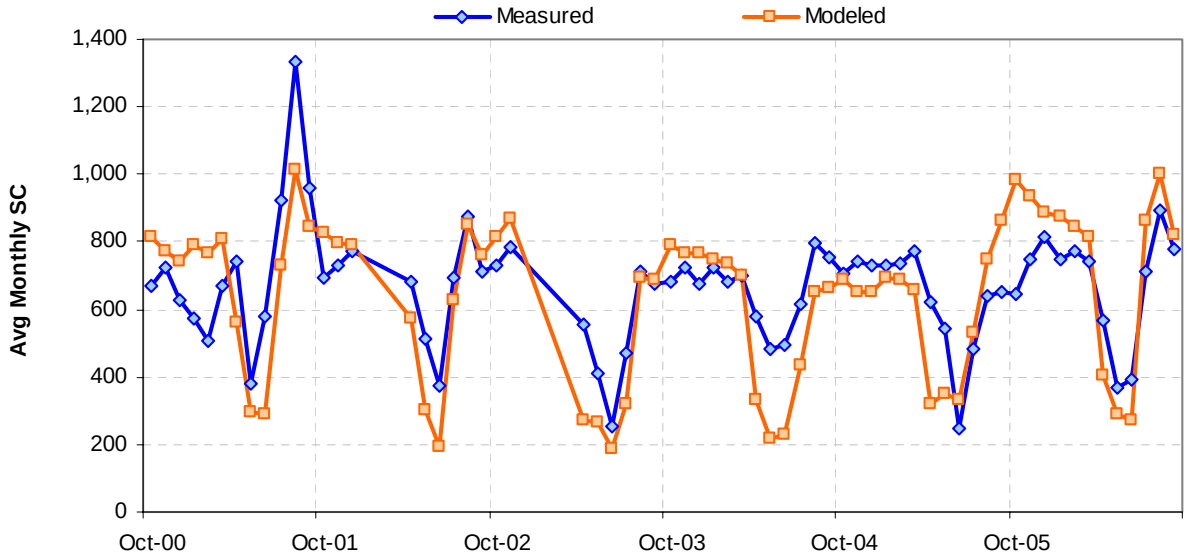

Figure B-23. Time series of average monthly salinity data for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

B.3.2.2 SAR

SAR values were computed for the Tongue River at USGS gage 06306300 where calcium, magnesium, and sodium were collected on the same day. Values were also obtained from the continuous SAR sampler maintained by USGS. The period of record at this gage for SAR is November 4, 1985 to present. During this period, SAR was collected at varying frequencies – monthly from November 1985 to August 2000, and daily from September 2000 to September 2006. The daily data collected between October 1, 2000 and September 30, 2006 were used for the SAR calibration. This data provided 6 years of nearly continuous SAR data with which to calibrate the LSPC model (n=1909, 87 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-24, Figure B-25, Figure B-26, Figure B-27, Figure B-28, and Table B-5.

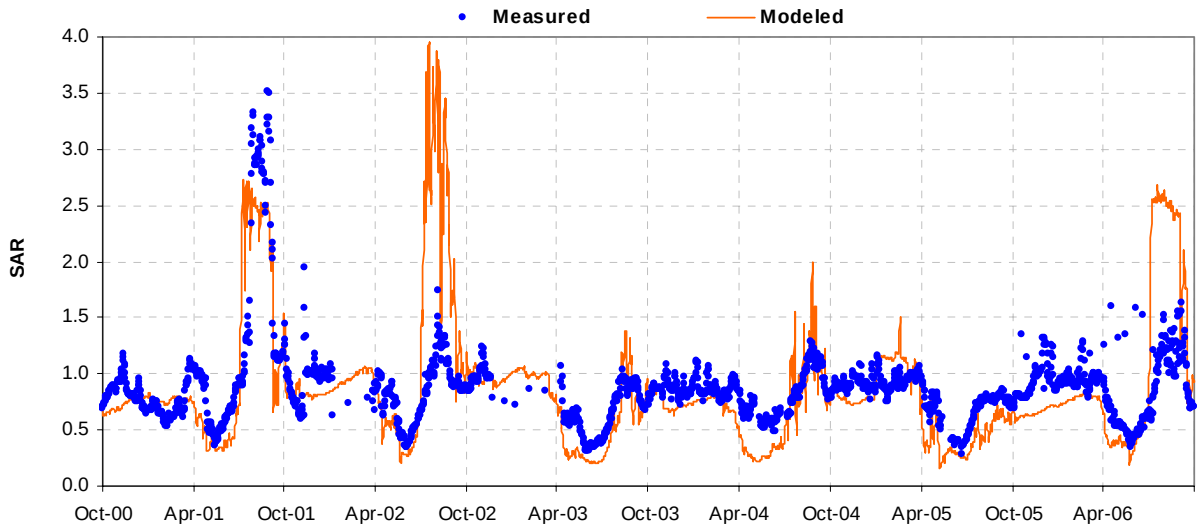

Figure B-24. Time series of continuous SAR data for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

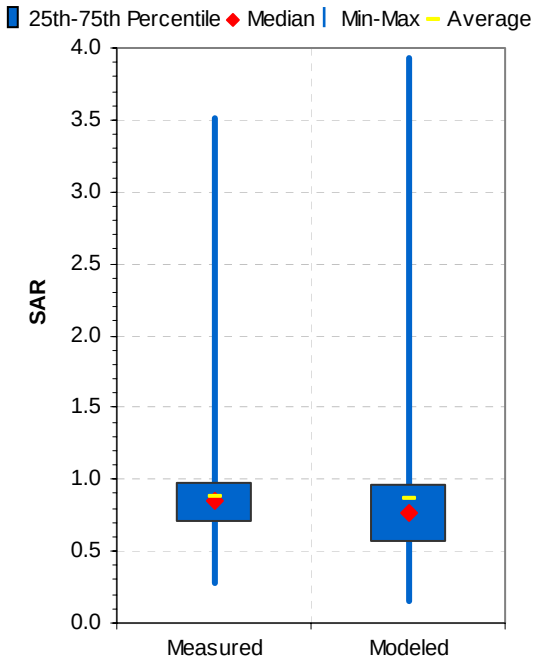

Figure B-25. Distribution of measured and modeled SAR data for the Tongue River at State Line near Decker, Montana (October 1, 2000 to September 30, 2006).

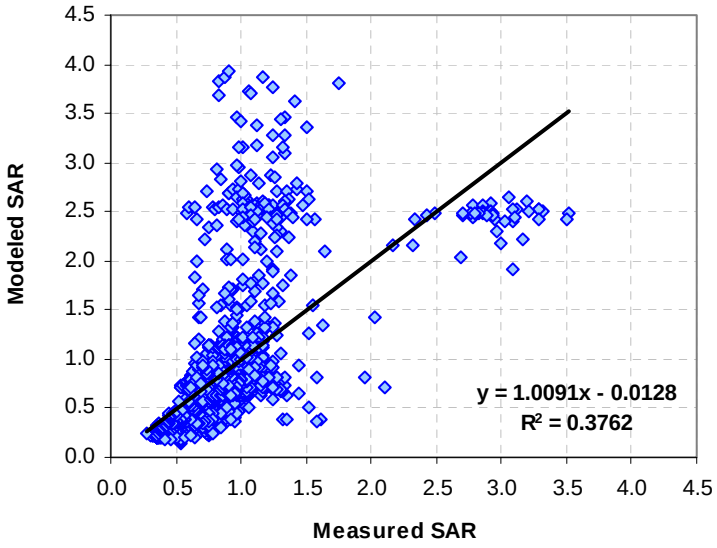

Figure B-26. Observed versus simulated scatter plot of average daily SAR values for the Tongue River at State Line, Montana (October 1, 2000 to September 30, 2006).

Table B-5. SAR Calibration Statistics for Tongue River at State Line, USGS Gage 06306300 (October 1, 2000 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SAR	Average SAR	Median SAR	Average SAR	Median SAR	Average SAR
All Data	0.74	0.88	0.85	0.88	-12.6%	-0.4%
Growing Season	0.67	0.91	0.81	0.87	-16.7%	4.1%
Non-growing Season	0.77	0.80	0.90	0.90	-14.6%	-10.7%
January	0.76	0.85	0.89	0.86	-13.8%	-1.6%
February	0.80	0.88	0.88	0.84	-9.3%	5.3%
March	0.78	0.80	0.94	0.91	-17.3%	-12.5%
April	0.41	0.46	0.75	0.79	-45.0%	-41.5%
May	0.31	0.33	0.53	0.55	-40.4%	-39.0%
June	0.34	0.36	0.48	0.52	-29.1%	-30.9%
July	1.15	1.51	0.78	0.88	47.5%	72.2%
August	1.56	1.73	1.09	1.36	44.1%	27.3%
September	0.86	1.02	0.90	1.01	-4.5%	1.3%
October	0.80	0.80	0.86	0.86	-7.0%	-6.9%
November	0.73	0.75	0.96	0.95	-23.8%	-21.4%
December	0.77	0.76	0.89	0.91	-13.6%	-16.2%

[1]**Observed data consist of daily data collected in the Tongue River at the State Line (USGS Gage 06306300). Months with less than 15 observed samples were excluded from this analysis.**

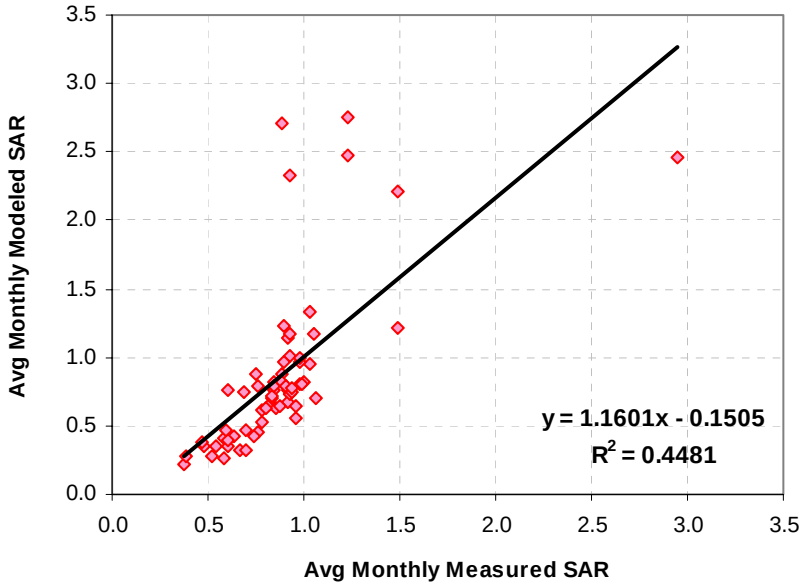

Figure B-27. Observed versus simulated scatter plot of average monthly SAR values for the Tongue River at State Line, Montana (October 1, 2000 to September 30, 2006).

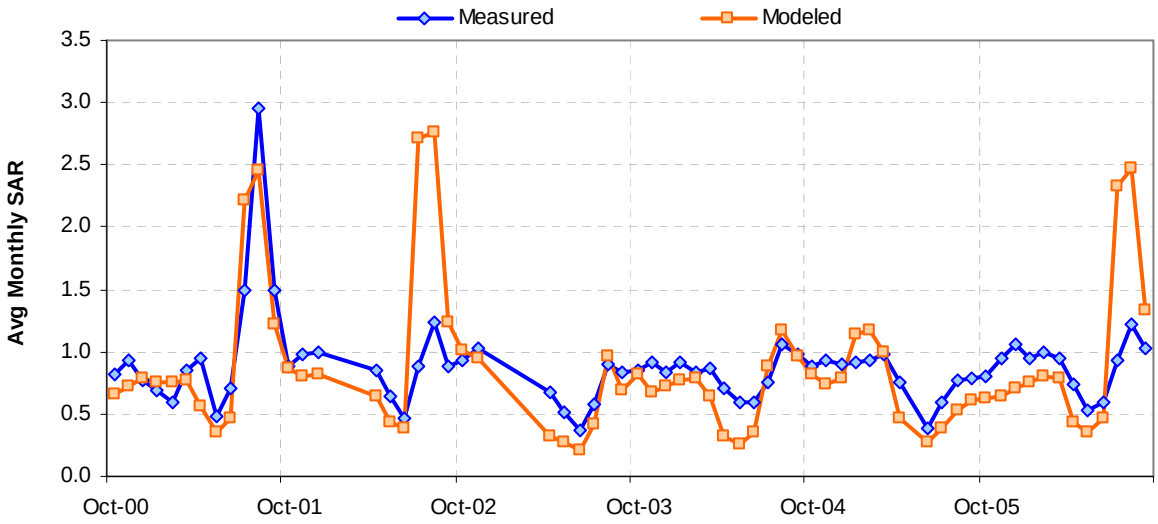

Figure B-28. Time series of average monthly SAR data for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

B.3.2.3 Total Nitrogen (TN)

TN data were available for the Tongue River at the state line (USGSG gage 06306300) from November 1985 to July 1988, and from June 2000 to August 2005. During these two periods, TN samples were collected at a monthly frequency. The period between June 1, 2000 and August 31, 2005 was selected for the TN calibration. The observed and simulated TN concentrations for the calibration period are shown in Figure B-29 and Figure B-30.

Due to the limited data (n=59), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating TN was a visual inspection of modeled and observed data.

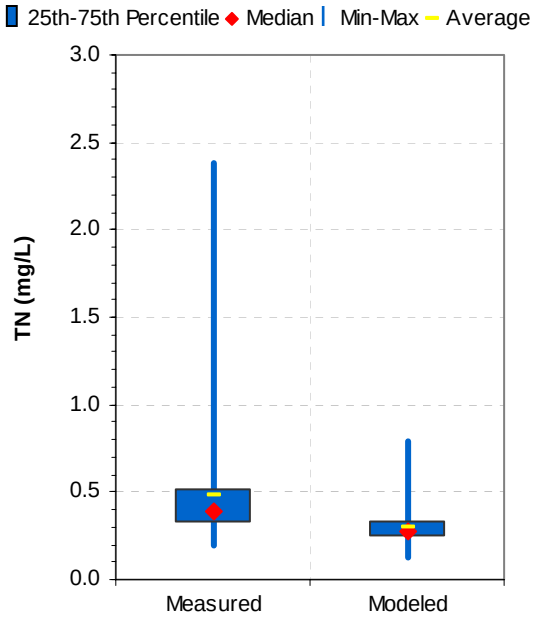

Figure B-29. Modeled and observed TN data for the Tongue River at USGS gage 06306300 (June 1, 2000 to August 31, 2005).

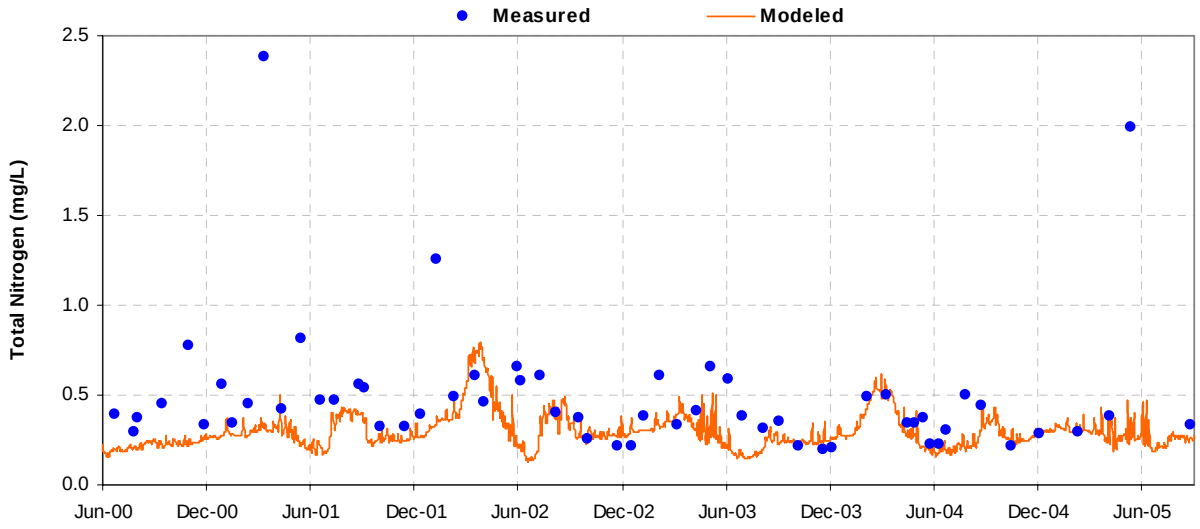

Figure B-30. Time series of TN data for the Tongue River at State Line near Decker, Montana (USGS gage 06306300).

B.3.2.4 Total Phosphorus (TP)

TP data were available for the Tongue River at the state line (USGSG gage 06306300) from November 4, 1985 to September 24, 1991, and from June 21, 2000 to present. During these two periods, TP samples were collected at a monthly frequency. The period between June 1, 2000 and September 30, 2006 was selected for the TP calibration. The observed and simulated TP concentrations for the calibration period are shown in Figure B-31 and Figure B-32.

Due to the limited data (n=65), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating TP was a visual inspection of modeled and observed data.

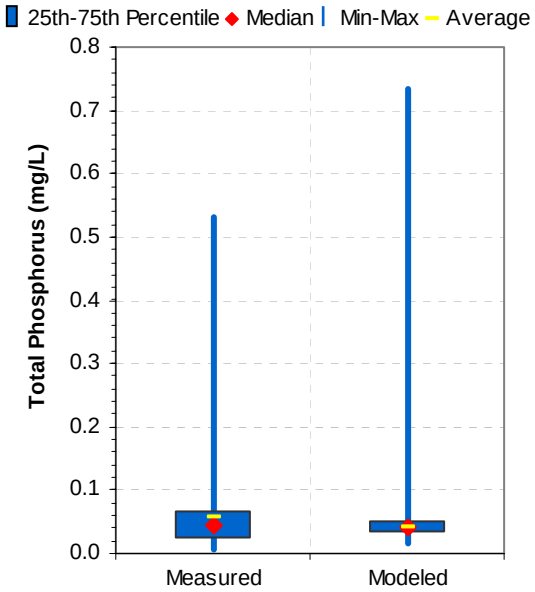

Figure B-31. Modeled and observed TP data for the Tongue River at State Line (June 1, 2000 to September 30, 2006).

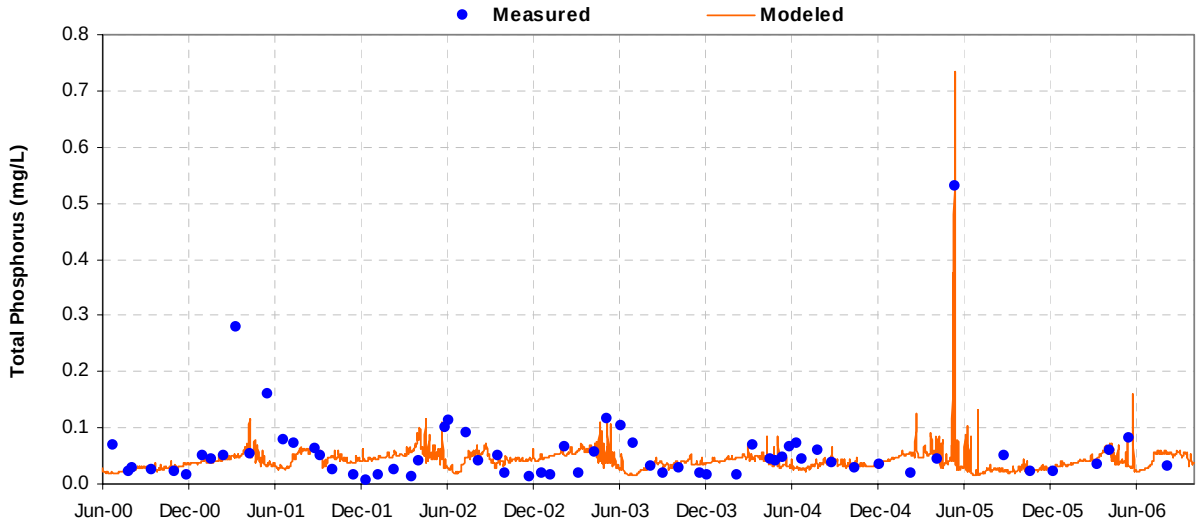

Figure B-32. Time series of TP data for the Tongue River at State Line near Decker, Montana (USGS Gage 06306300).

B.3.2.5 Water Temperature

Water temperature data were available for the Tongue River at the State Line (USGS gage 06306300) from October 16, 1985 to present. During this period, temperature samples were generally collected at a monthly frequency. The 14-year period between October 1, 1992 and September 30, 2006 was selected for the water temperature calibration. The observed and simulated temperatures for the calibration period are shown in Figure B-33 and Figure B-34.

Due to the limited data (monthly data, n=159), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating temperature was a visual inspection of modeled and observed data.

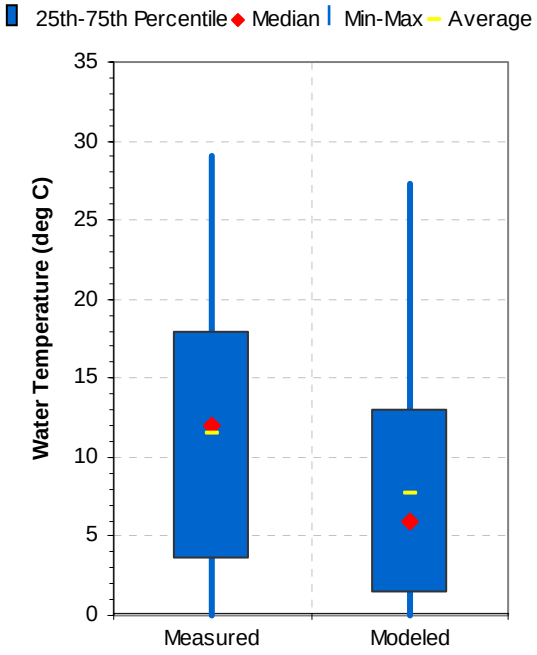

Figure B-33. Modeled and observed water temperature data for the Tongue River at State Line (October 1, 1992 to September 30, 2006).

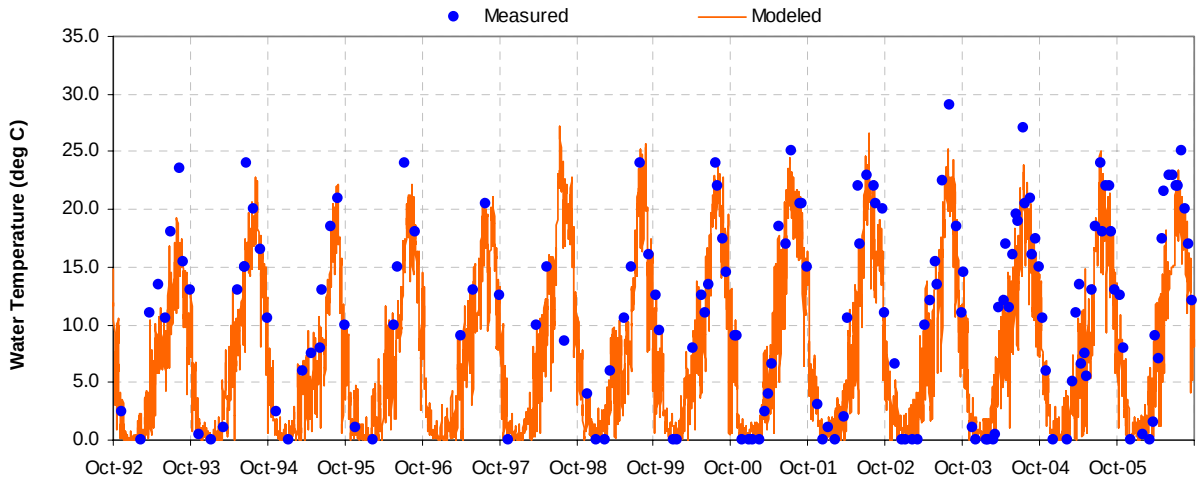

Figure B-34. Time series of water temperature data for the Tongue River at State Line near Decker, Montana (USGS Gage 06306300).

B.4 Tongue River below the Tongue River Reservoir Dam near Decker, Montana

The Tongue River below the Tongue River Reservoir (TRR) Dam near Decker, Montana USGS gaging station (Gage ID 06307500) is located at latitude 45.14137º, longitude -106.77145º (NAD83) in Big Horn County, Montana, Hydrologic Unit 10090101 (USGS, 2004). The gage elevation is 3,344 feet (NGVD 29), and the gage has a watershed area of 1,770 square miles. USGS reports a bankfull width of 112 feet and a mean bankfull depth of 3.0 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 3000, and the gage measures the overflows and managed releases from the Tongue River Reservoir. Because of the limited data available within the reservoir, this USGS gage was used to calibrate salinity and SAR for the Tongue River Reservoir. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-35.

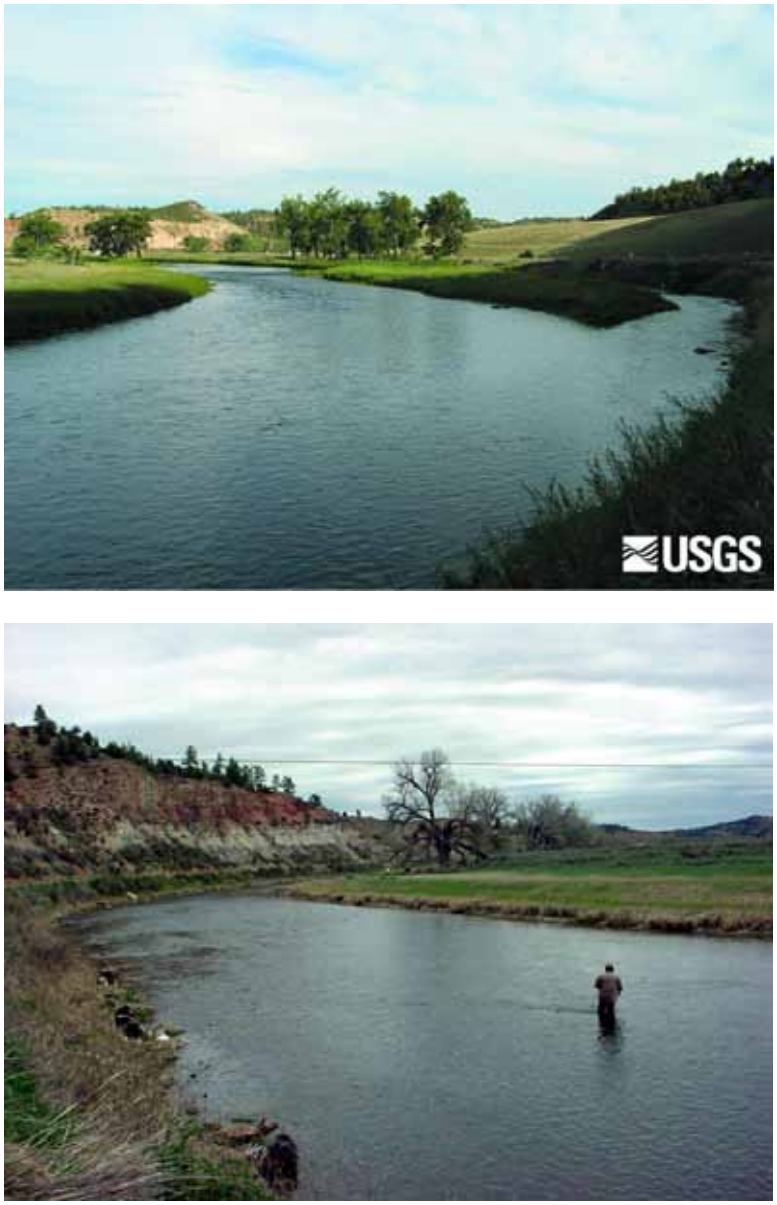

Figure B-35. Tongue River below the Tongue River Reservoir Dam, Montana (06307500). Photos by USGS and Tetra Tech, Inc.

B.4.1 Hydrology

Discharge data are available for the Tongue River below the Tongue River Reservoir Dam at USGS gage 06307500. The period of record at this gage for flow is 1939 to present and the record is 100 percent complete. The six-year period between October 1, 2000 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The Tongue River Reservoir was rehabilitated between 1996 and 1999, raising the storage capacity from 68,000 to 79,000 acre-feet (DNRC, 2004). The LSPC model cannot account for varying dam heights or storage volumes; therefore, LSPC was only setup for post-rehabilitation conditions. The first full year of normal operation after the rehabilitation was 2000.
- The entire period between October 1, 2000 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal and dry years, but does not include wet years (see Section 4.1 of the Modeling Report).

Daily and monthly average calibration graphs and statistics are provided in Figure B-36, Figure B-37, Figure B-38, Figure B-39, and Table B-6.

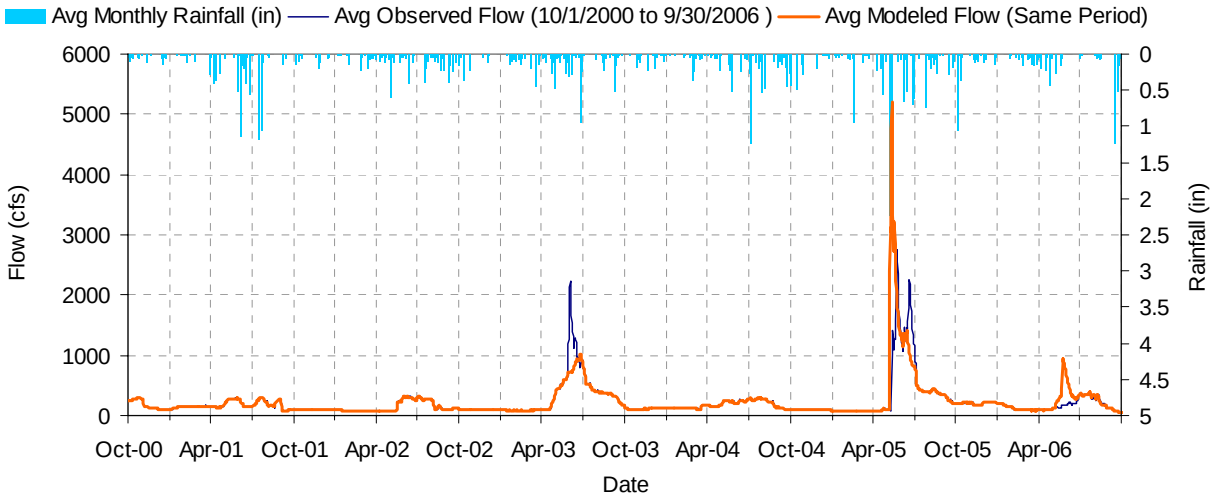

Figure B-36. Time series of hydrologic calibration results (daily mean) for the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500).

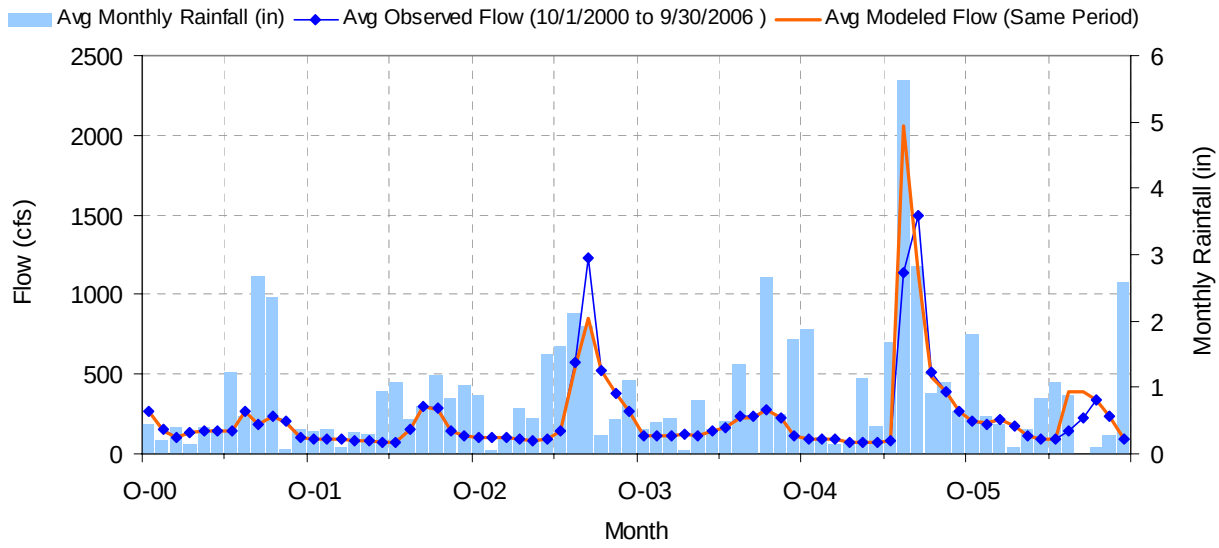

Figure B-37. Time series of hydrologic calibration results (monthly mean) for the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500).

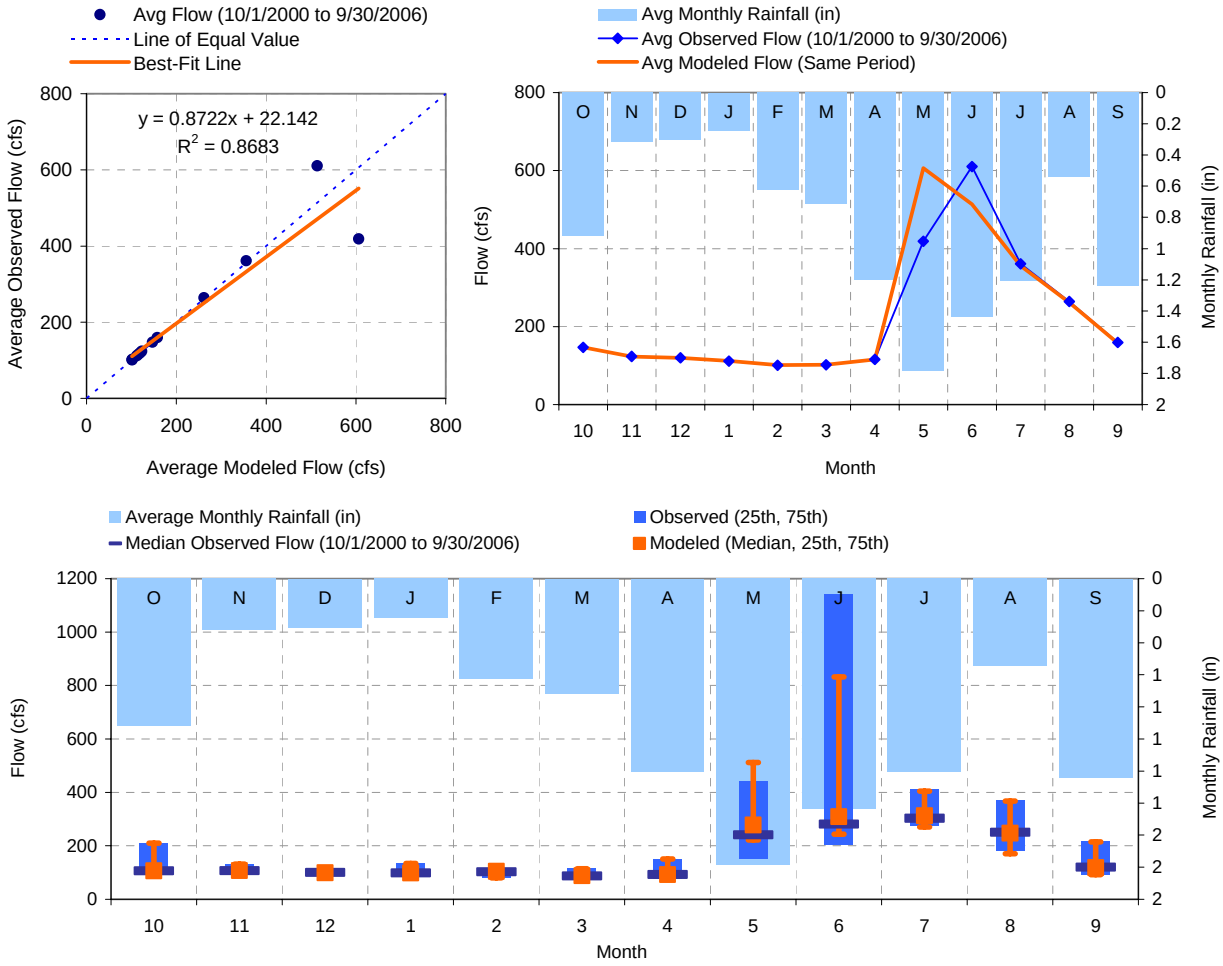

Figure B-38. Composite (average monthly) hydrologic calibration results for the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500) (October 1, 2000 to September 30, 2006).

Table B-6. Hydrologic calibration statistics for Tongue River below the Tongue River Reservoir Dam, USGS Gage 06307500 (October 1, 2000 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	987,594	129	227	956,458	127	220	3.3%	1.9%	3.3%
Growing Season	824,073	188	283	793,144	177	272	3.9%	6.3%	3.9%
Non-growing Season	163,521	105	114	163,313	105	114	0.1%	0.0%	0.1%
January	41,284	98	112	41,219	98	112	0.2%	0.5%	0.2%
February	33,991	104	101	33,894	103	101	0.3%	1.1%	0.3%
March	37,633	88	102	37,577	88	102	0.1%	0.8%	0.1%
April	41,281	92	116	41,306	92	116	-0.1%	0.3%	-0.1%
May	223,710	278	606	154,493	241	419	44.8%	15.2%	44.8%
June	183,406	309	514	217,936	281	610	-15.8%	10.1%	-15.8%
July	131,097	313	355	133,256	303	361	-1.6%	3.3%	-1.6%
August	96,534	247	262	97,500	251	264	-1.0%	-1.5%	-1.0%
September	56,218	118	157	56,850	120	159	-1.1%	-1.3%	-1.1%
October	54,195	106	147	54,228	106	147	-0.1%	0.3%	-0.1%
November	43,952	107	123	43,985	107	123	-0.1%	-0.3%	-0.1%
December	44,295	100	120	44,216	100	120	0.2%	-0.4%	0.2%
10% Highest Flows	955,677	145	244	923,266	143	236	3.5%	1.5%	3.4%
10% Lowest Flows	31,759	73	73	33,191	73	73	-4.3%	0.0%	-0.1%

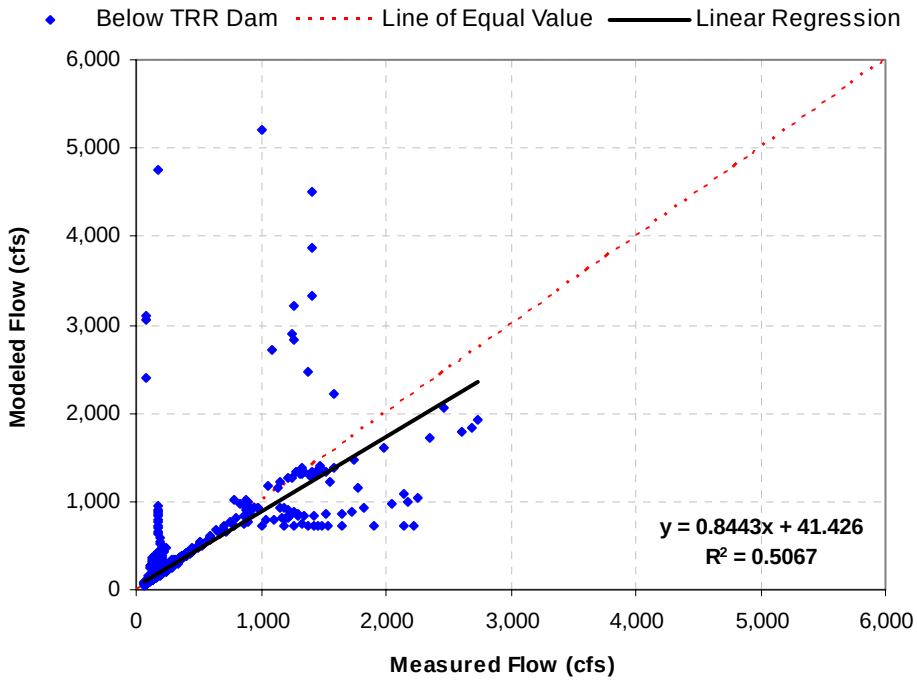

Figure B-39. Observed versus simulated scatter plot of average daily values for the Tongue River below the Tongue River Reservoir Dam, Montana (October 1, 2000 to September 30, 2006).

B.4.2 Water Quality

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in the Tongue River to supplement the water quality impairment analysis for salinity and sodium adsorption ration (SAR) (as described in USEPA, 2007). Data were collected at USGS Gage 06307500 (Tongue River below the Tongue River Reservoir Dam) at varying frequencies from 1975 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration.

B.4.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for the Tongue River below the Tongue River Reservoir Dam at USGS gage 06307500. The period of record at this gage for salinity is 1975 to present. During this period, samples were collected at varying frequencies. Daily data were collected from November 1, 1980 to December 31, 1986, and from May 1, 2004 to present. The daily data collected between May 1, 2004 and September 30, 2006 were used for the salinity calibration. This data provided 2.5 years of nearly continuous SC data with which to calibrate the LSPC model (n=786, 89 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-40, Figure B-41, Figure B-42, Figure B-43, and Table B-7.

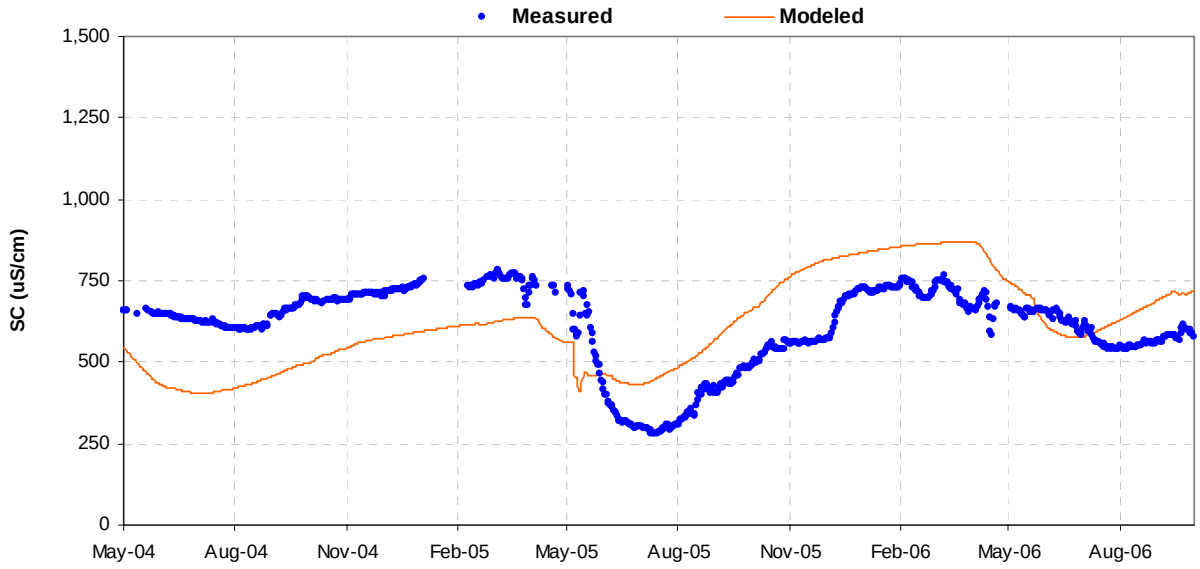

Figure B-40. Time series of salinity data for the Tongue River below the Tongue River Reservoir Dam (USGS gage 06307500).

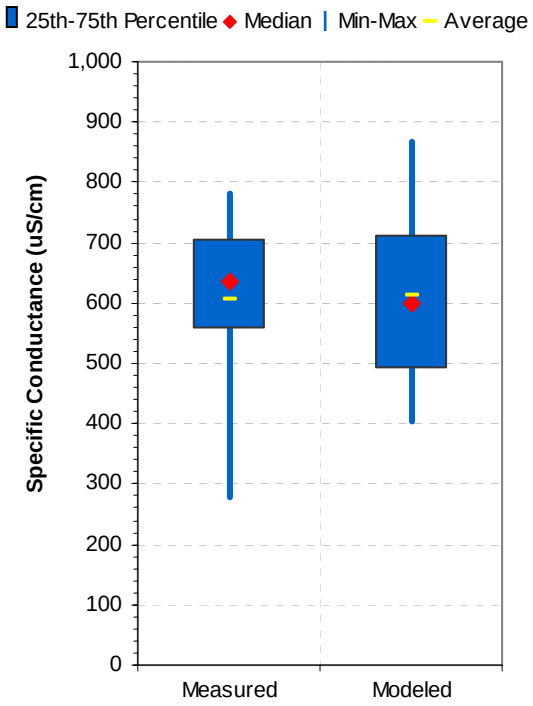

Figure B-41. Distribution of measured and modeled salinity data for the Tongue River below the Tongue River Reservoir Dam (May 1, 2004 to September 30, 2006).

Table B-7. Salinity calibration statistics for Tongue River below the Tongue River Reservoir Dam, Montana. (May 1, 2004 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC	Average SC
All Data	598	619	635	606	-5.8%	2.2%
Growing Season	581	580	609	577	-4.7%	0.6%
Non-growing Season	802	733	714	690	12.3%	6.1%
January	847	846	727	725	16.5%	16.7%
February	856	764	735	731	16.4%	4.4%
March	753	751	749	733	0.6%	2.5%
April	825	769	691	691	19.4%	11.3%
May	502	559	652	636	-23.0%	-12.0%
June	439	484	628	534	-30.1%	-9.4%
July	461	494	555	490	-16.9%	0.7%
August	525	545	550	510	-4.6%	6.9%
September	627	607	581	564	8.0%	7.8%
October	666	627	561	605	18.8%	3.7%
November	670	678	631	634	6.2%	7.0%
December	704	705	717	697	-1.8%	1.2%

[1]**Observed data consist of daily data collected in the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500). Months with less than 15 observed samples were excluded from this analysis.**

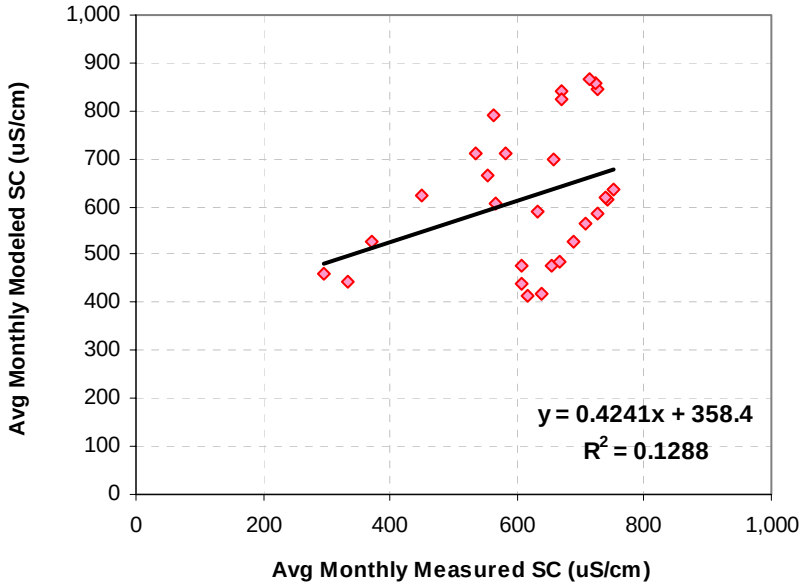

Figure B-42. Observed versus simulated scatter plot of average monthly SC values for the Tongue River below the Tongue River Reservoir Dam (May 1, 2004 to September 30, 2006).

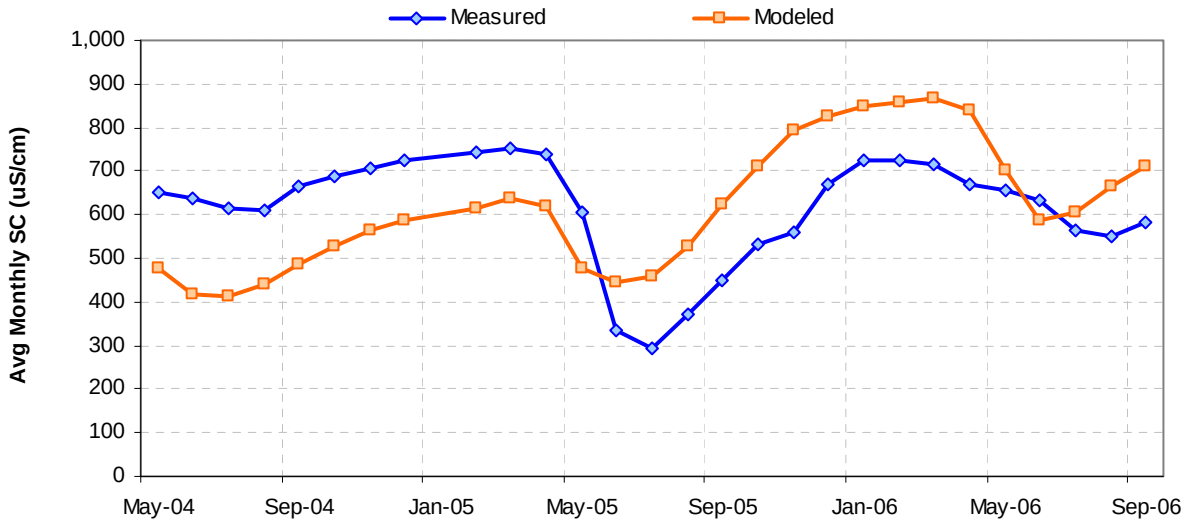

Figure B-43. Time series of average monthly salinity data for the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500).

B.4.2.2 SAR

SAR values were computed for the Tongue River at USGS gage 06307500 where calcium, magnesium, and sodium were collected on the same day. The period of record at this gage for SAR is October 7, 1975 to August 29, 1995, and January 20, 2004 to present. During these periods, samples were collected at varying frequencies. The period between January 1, 2004 and September 30, 2006 was chosen for water quality calibration because it had the most recent post rehabilitation SAR data. The observed and simulated SAR values for the calibration period at this gage are shown in Figure B-44 and Figure B-45.

Due to the limited observed data (n=51), it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. Therefore, the primary method for calibrating SAR was a visual inspection of modeled and observed data.

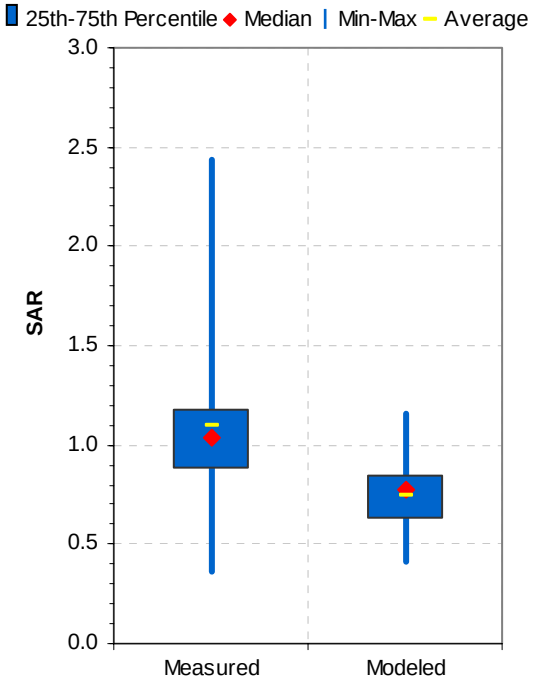

Figure B-44. Distribution of measured and modeled SAR data for the Tongue River below the Tongue River Reservoir Dam (January 1, 2004 to September 30, 2006).

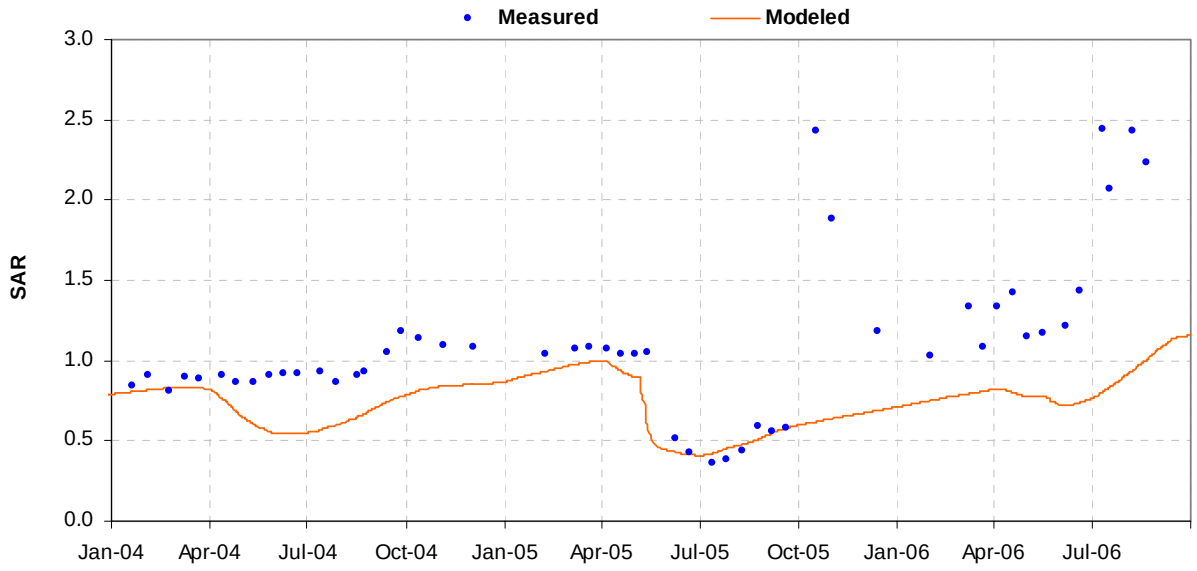

Figure B-45. Time series of SAR data for the Tongue River below the Tongue River Reservoir Dam, Montana (USGS Gage 06307500).

B.5 Tongue River below Brandenberg Bridge near Ashland, Montana

The Tongue River below the Brandenberg Bridge near Ashland, Montana USGS gaging station (Gage ID 06307830) is located at latitude 45.83972º, longitude -106.21973º (NAD83) in Rosebud County, Montana, Hydrologic Unit 10090102 (USGS, 2004). The gage elevation is 2,760 feet (NGVD 29), and the gage has a watershed area of 3,948 square miles. USGS reports a bankfull width of 98 feet and a mean bankfull depth of 3.3 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 1047. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-46.

Figure B-46. Tongue River at USGS Gage Tongue River below the Brandenberg Bridge, Montana (06307830). Photos by USGS.

B.5.1 Hydrologic Calibration

Discharge data are available for the Tongue River below the Brandenberg Bridge at USGS gage 06307830. The period of record at this gage for flow is 1973 to 1984, and from July 1, 2000 to present. The record is 100 percent complete during these two periods. The six-year period between October 1, 2000 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The Tongue River Reservoir was rehabilitated between 1996 and 1999, raising the storage capacity from 68,000 to 79,000 acre-feet (DNRC, 2004). The LSPC model cannot account for varying dam heights or storage volumes; therefore, LSPC was only setup for post-rehabilitation conditions. The first full year of normal operation after the rehabilitation was 2000.
- The entire period between October 1, 2000 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal and dry years, but does not include wet years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-47, Figure B-48 Figure B-49, Figure B-50, and Table B-8.

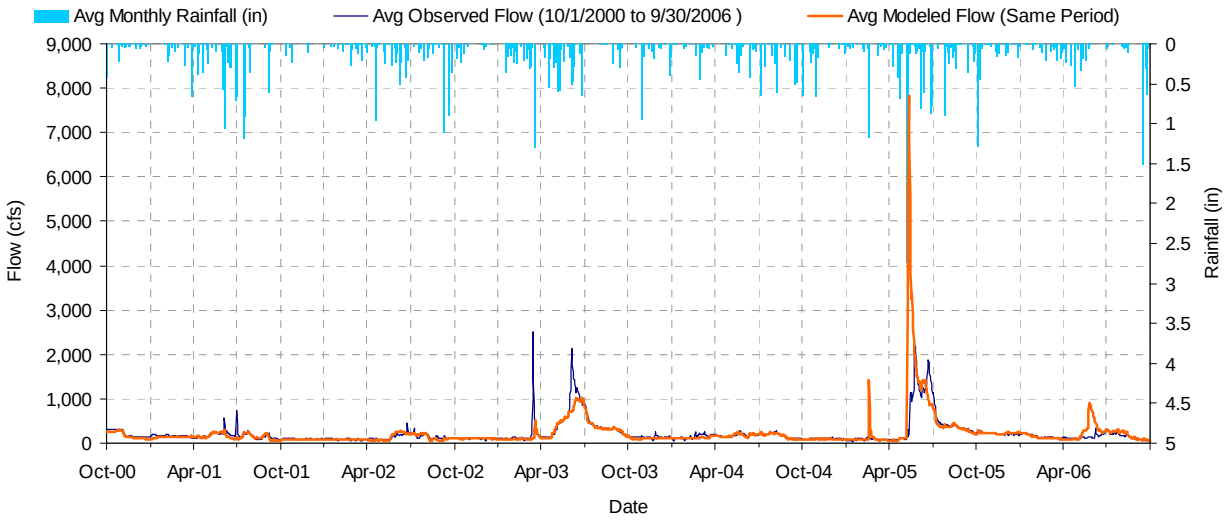

Figure B-47. Hydrologic calibration results (daily mean) for the Tongue River near the Brandenberg Bridge, Montana (USGS gage 06307830).

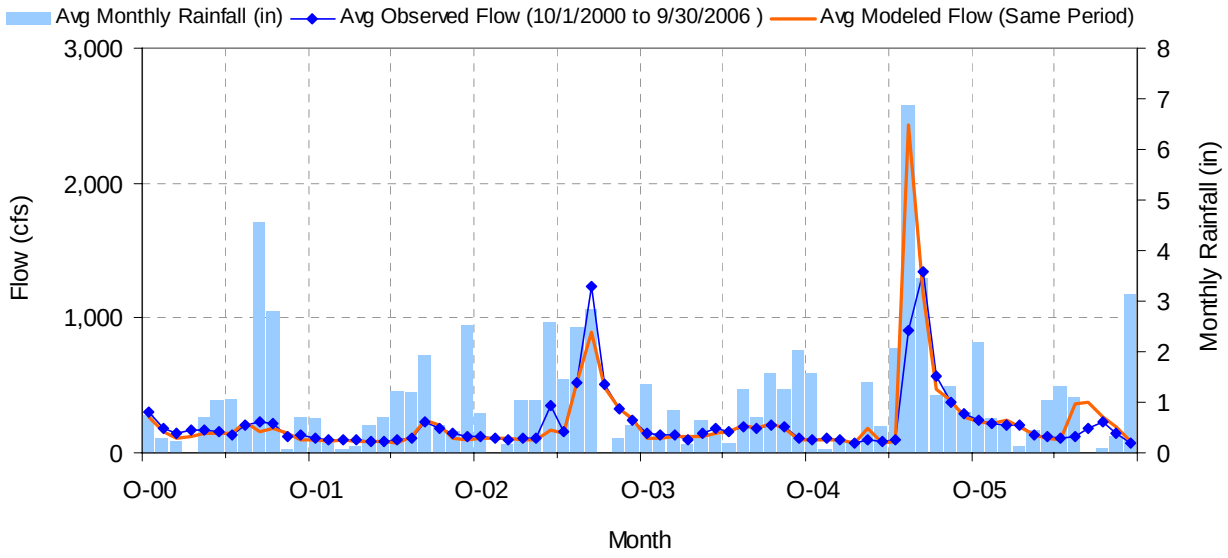

Figure B-48. Hydrologic calibration results (monthly mean) for the Tongue River below the Brandenberg Bridge, Montana (USGS gage 06307830).

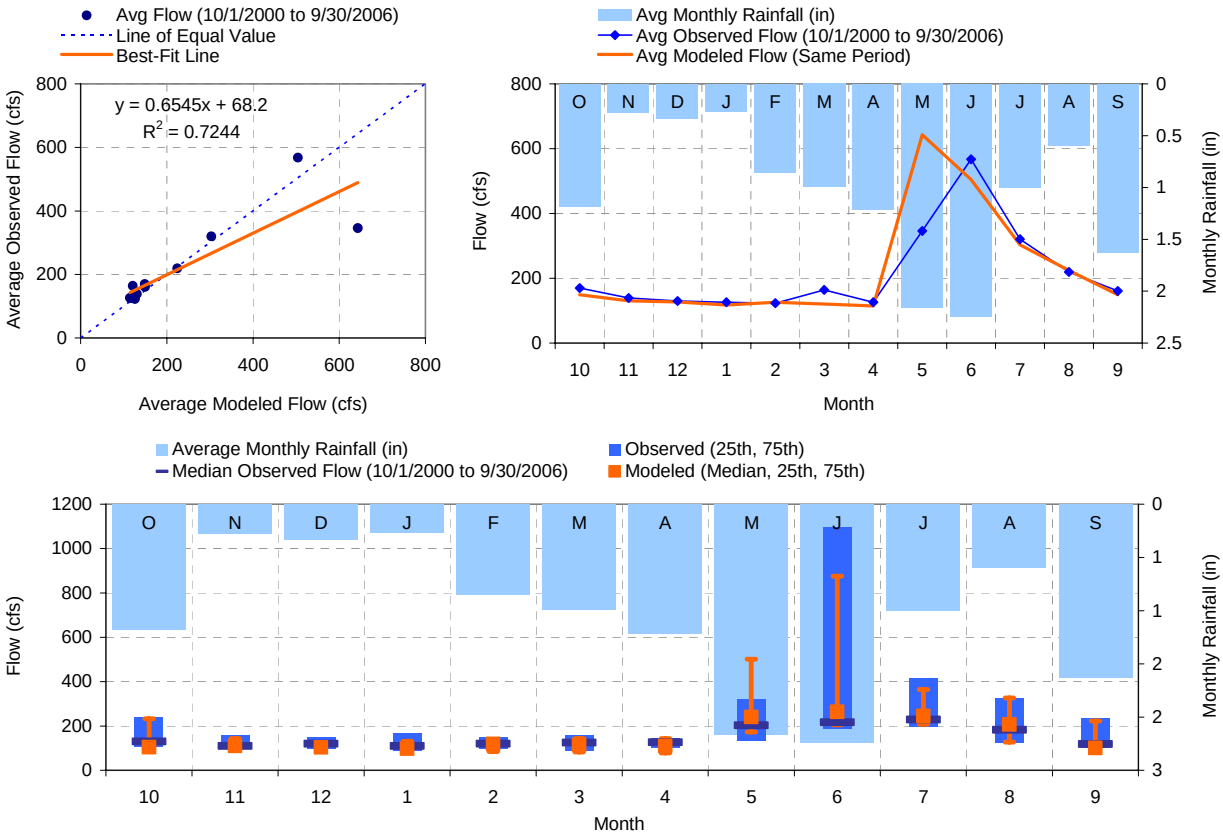

Figure B-49. Composite (average monthly) hydrologic calibration results for the Tongue River below the Brandenberg Bridge, Montana (October 1, 2000 to September 30, 2006).

Table B-8. Hydrologic calibration statistics for Tongue River below the Brandenberg Bridge, Montana (October 1, 2000 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	984,247	125	226	939,917	145	216	4.7%	-13.7%	4.7%
Growing Season	805,416	166	276	754,473	164	259	6.8%	1.3%	6.8%
Non-growing Season	178,831	108	125	185,445	110	130	-3.6%	-1.7%	-3.6%
January	43,279	98	117	46,562	110	126	-7.1%	-10.7%	-7.1%
February	42,322	119	126	41,272	120	123	2.5%	-0.8%	2.5%
March	44,542	116	121	60,417	126	164	-26.3%	-7.8%	-26.3%
April	40,870	110	114	44,959	126	126	-9.1%	-13.0%	-9.1%
May	237,236	241	643	127,609	204	346	85.9%	18.4%	85.9%
June	180,025	264	504	202,528	217	567	-11.1%	22.0%	-11.1%
July	111,904	245	303	118,126	229	320	-5.3%	7.1%	-5.3%
August	82,684	207	224	80,928	182	219	2.2%	13.9%	2.2%
September	53,254	101	149	57,346	119	161	-7.1%	-14.8%	-7.1%
October	54,901	105	149	62,561	130	170	-12.2%	-19.1%	-12.2%
November	46,580	110	130	49,630	110	139	-6.1%	-0.3%	-6.1%
December	46,651	104	126	47,980	120	130	-2.8%	-13.7%	-2.8%
10% Highest Flows	953,556	143	244	901,484	153	230	5.8%	-6.5%	6.0%
10% Lowest Flows	30,535	73	70	38,434	91	92	-20.6%	-20.3%	-23.2%

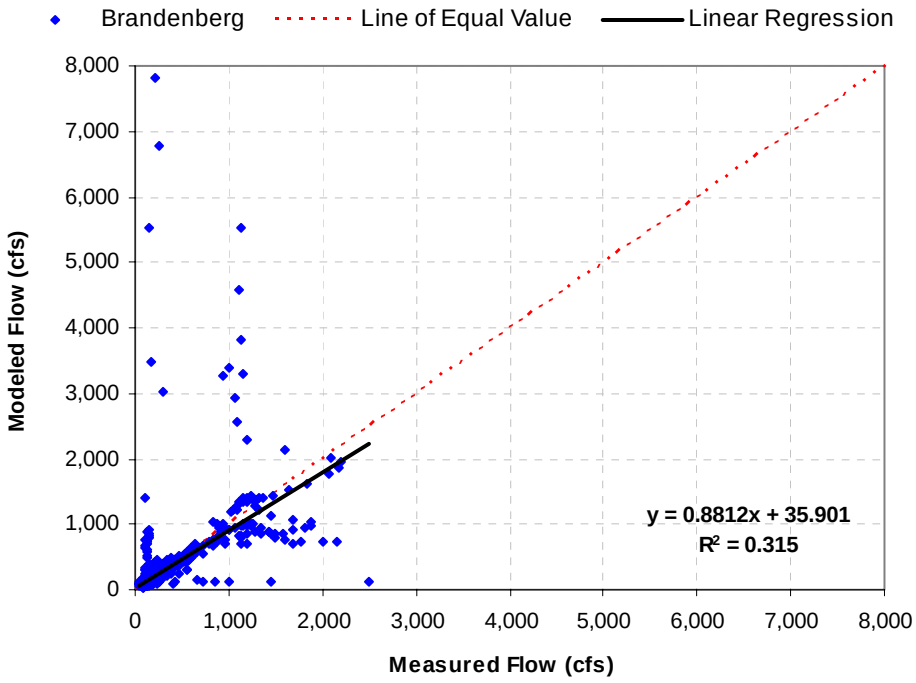

Figure B-50. Observed versus simulated scatter plot of average daily values for the Tongue River below the Brandenberg Bridge, Montana (October 1, 2000 to September 30, 2006).

B.5.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in the Tongue River to supplement the water quality impairment analysis for salinity and sodium adsorption ratio (SAR) (as described in the Assessment Report; USEPA, 2007). Data were collected at USGS Gage 06307830 (Tongue River below the Brandenberg Bridge) at varying frequencies from 1974 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration for the Tongue River below the Brandenberg Bridge.

B.5.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for the Tongue River below the Brandenberg Bridge at USGS Gage 06307830. The period of record at this gage for salinity is June 13, 2000 to present. During this period, samples were collected at varying frequencies. Daily data were collected from August 24, 2000 to present. The daily data collected between October 1, 2000 and September 30, 2006 were used for the salinity calibration. This time period provided 6 years of nearly continuous SC data with which to calibrate the LSPC model (n=1496, 68 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-51, Figure B-52, Figure B-53, Figure B-54, Figure B-55, and Table B-9.

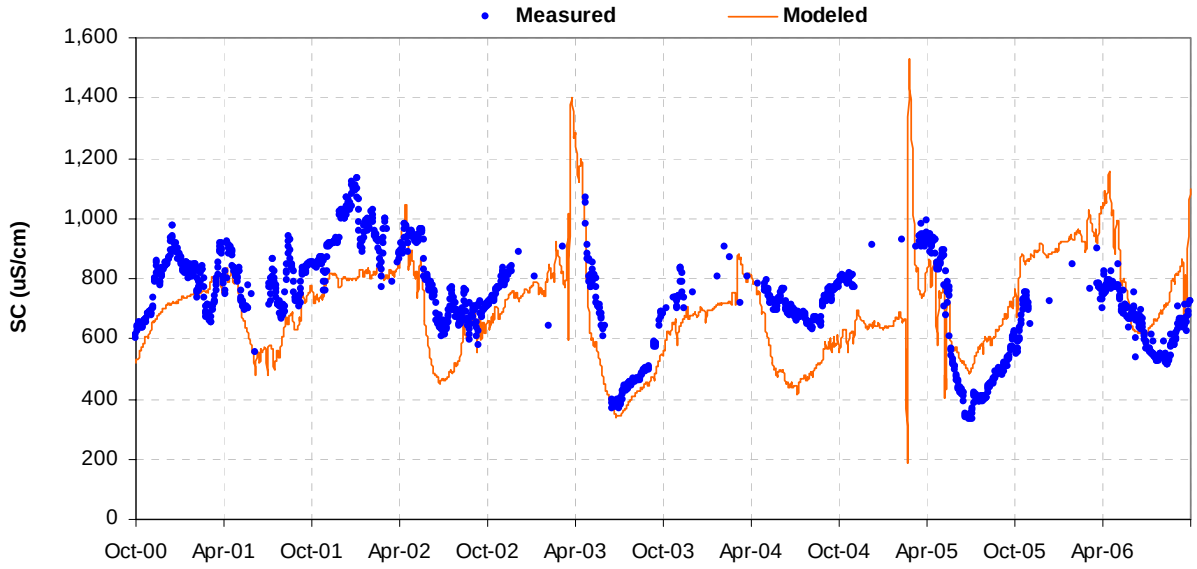

Figure B-51. Time series of salinity data for the Tongue River below the Brandenberg Bridge, Montana (USGS Gage 06307830).

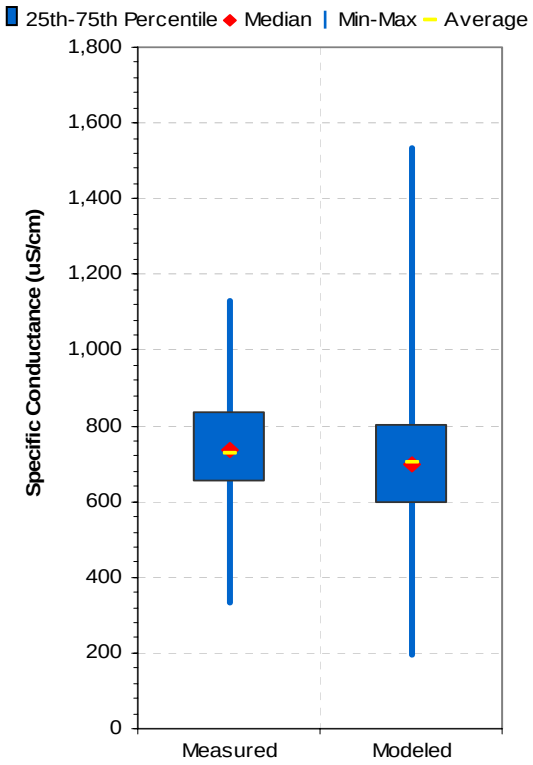

Figure B-52. Distribution of measured and modeled salinity data for the Tongue River below the Brandenberg Bridge (October 1, 2000 to September 30, 2006).

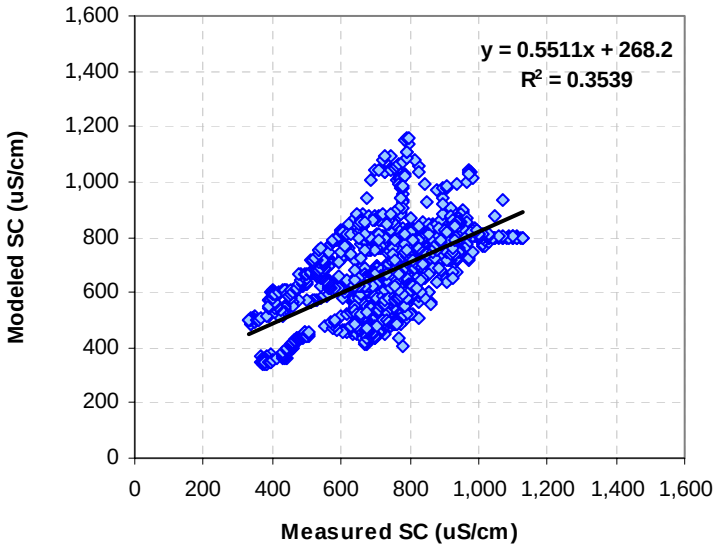

Figure B-53. Observed versus simulated scatter plot of average daily SC values for the Tongue River below the Brandenberg Bridge (October 1, 2000 to September 30, 2006).

Table B-9. Salinity calibration statistics for Tongue River below the Brandenberg Bridge, Montana. (October 1, 2000 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)
All Data	662	664	729	723	-9.1%	-8.1%
Growing Season	625	642	701	685	-10.9%	-6.3%
Non-growing Season	758	763	876	891	-13.4%	-14.4%
January	775	778	883	911	-12.1%	-14.6%
February	782	790	837	848	-6.6%	-6.9%
March	797	787	880	828	-9.4%	-5.0%
April	850	888	881	863	-3.5%	2.9%
May	634	657	735	752	-13.8%	-12.7%
June	495	506	658	589	-24.7%	-14.1%
July	504	513	592	577	-14.9%	-11.2%
August	608	592	605	604	0.4%	-2.0%
September	665	675	693	680	-3.9%	-0.9%
October	670	685	751	741	-10.8%	-7.6%
November	731	736	830	845	-12.0%	-12.9%
December	730	757	974	968	-25.1%	-21.8%

[1]**Observed data consist of daily data collected in the Tongue River below the Brandenberg Bridge, MT (USGS Gage 06307830). Months with less than 15 observed samples were excluded from this analysis.**

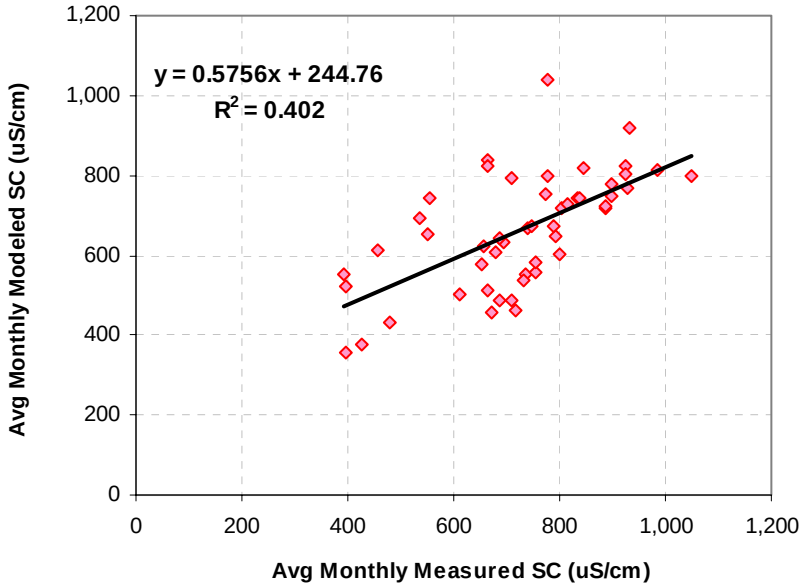

Figure B-54. Observed versus simulated scatter plot of average monthly SC values for the Tongue River below the Brandenberg Bridge (October 1, 2000 to September 30, 2006).

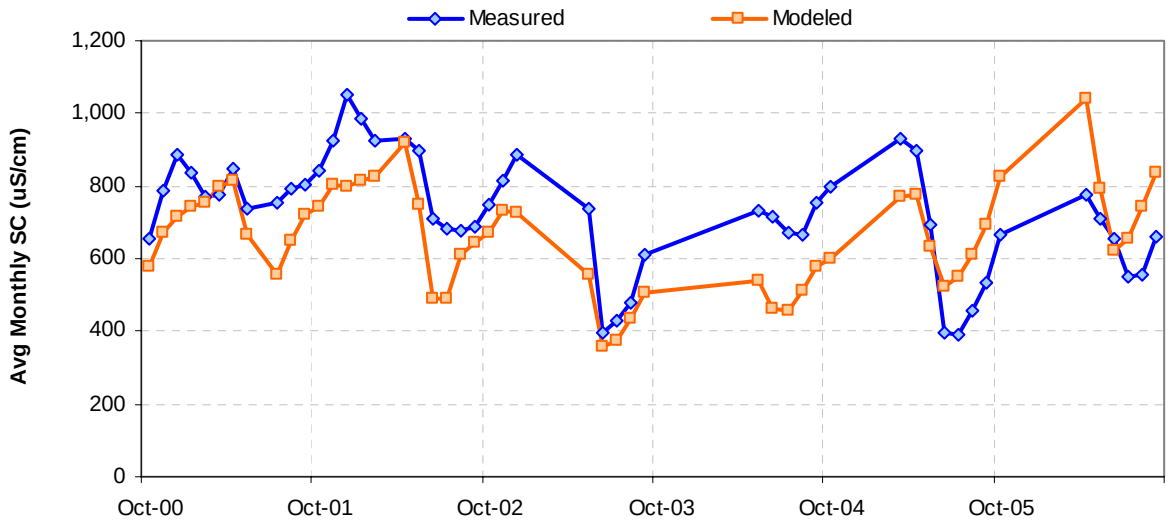

Figure B-55. Time series of average monthly salinity data for the Tongue River below the Brandenberg Bridge (USGS gage 06307830).

B.5.2.2 SAR

SAR data are available for the Tongue River below the Brandenberg Bridge at USGS Gage 06307830. The period of record at this gage for SAR is October 1974 to September 1981, and from June 2000 to present. During these periods, samples were collected at varying frequencies. Daily data were collected from October 24, 2003 to present. The data collected between November 1, 2003 and September 30, 2006 were used for the SAR calibration. This time period provided almost three years of nearly continuous SAR data with which to calibrate the LSPC model (n=608, 57 percent complete). No daily SAR data were available during the nongrowing season (November-March). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-56, Figure B-57, Figure B-58, Figure B-59, Figure B-60, and Table B-10.

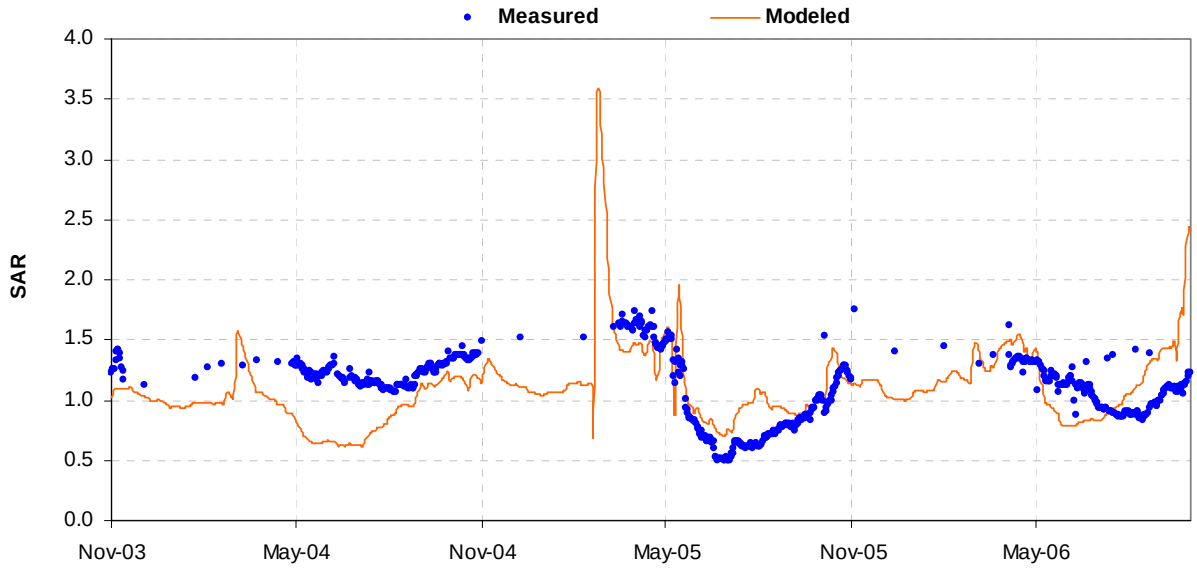

Figure B-56. Time series of continuous SAR data for the Tongue River near the Brandenberg Bridge, Montana (USGS Gage 06307830).

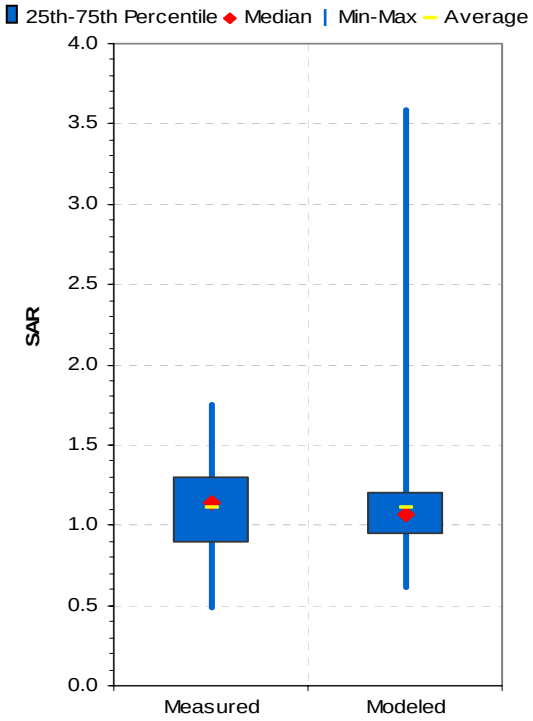

Figure B-57. Distribution of measured and modeled SAR data for the Tongue River below the Brandenberg Bridge (November 1, 2003 to September 30, 2006).

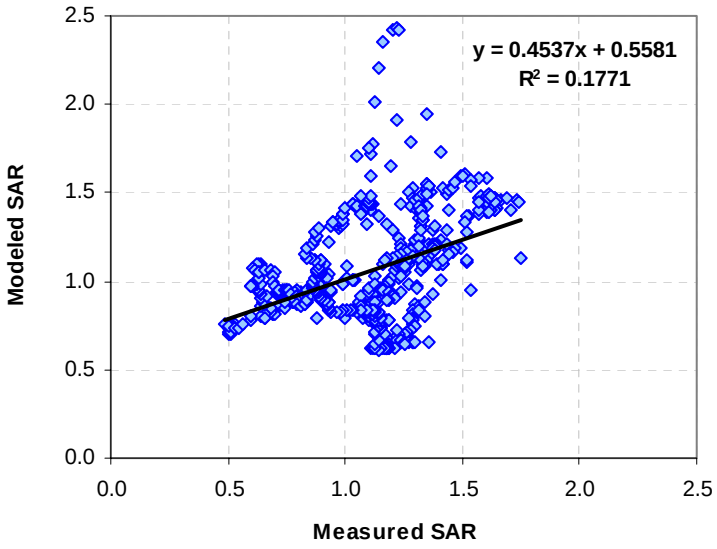

Figure B-58. Observed versus simulated scatter plot of average daily SAR values for the Tongue River below the Brandenberg Bridge (November 1, 2003 to September 30, 2006).

Table B-10.SAR Calibration Statistics for Tongue River below the Brandenberg Bridge, Montana. (November 1, 2003 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SAR	Average SAR	Median SAR	Average SAR	Median SAR	Average SAR
All Data	0.97	1.06	1.13	1.09	-14.1%	-3.2%
Growing Season	0.97	1.06	1.13	1.09	-14.1%	-3.2%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	1.42	1.43	1.62	1.62	-12.2%	-11.5%
April	1.46	1.43	1.43	1.45	2.2%	-1.3%
May	0.91	0.99	1.21	1.20	-24.7%	-17.1%
June	0.79	0.75	1.10	0.96	-28.3%	-21.5%
July	0.87	0.86	0.90	0.89	-2.9%	-2.9%
August	0.97	1.04	0.89	0.93	8.7%	12.3%
September	1.13	1.24	1.10	1.08	3.0%	15.5%
October	1.18	1.19	1.28	1.24	-7.5%	-4.0%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in the Tongue River below the Brandenberg Bridge (USGS Gage 06307830). Months with less than 15 observed samples were excluded from this analysis.**

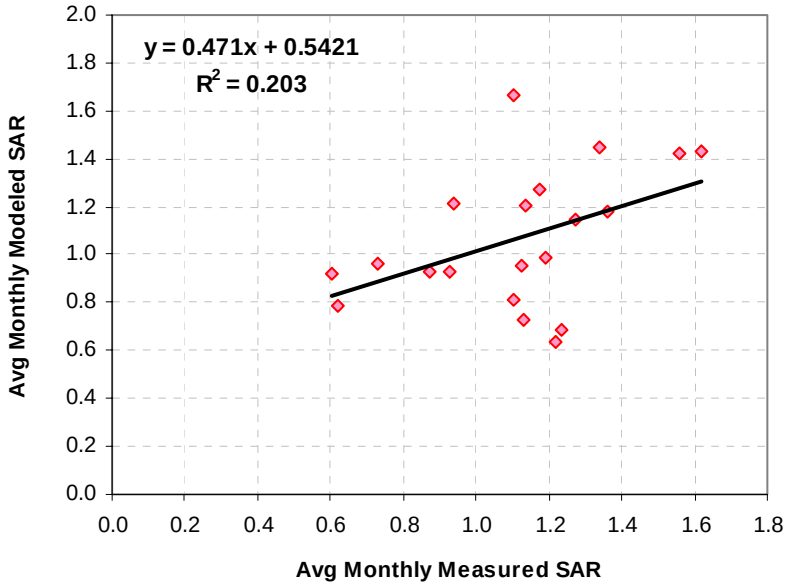

Figure B-59. Observed versus simulated scatter plot of average monthly SAR values for the Tongue River below the Brandenberg Bridge (November 1, 2003 to September 30, 2006).

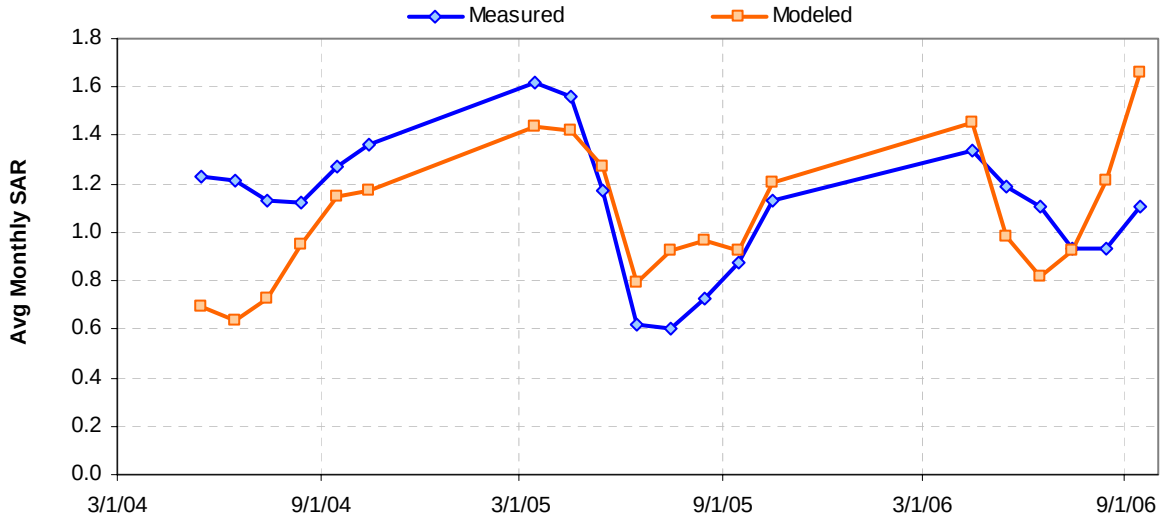

Figure B-60. Time series of average monthly SAR data for the Tongue River below the Brandenberg Bridge (USGS gage 06307830).

B.6 Tongue River at Miles City, Montana

The Tongue River at Miles City, Montana USGS gaging station (Gage ID 06308500) is located at latitude 46.384725º, longitude -105.84528º (NAD83) in Custer County, Montana, Hydrologic Unit 10090102 (USGS, 2004). The gage elevation is 2,360 feet (NGVD 29), and the gage has a watershed area of 5,379 square miles. The gage at Miles City is the most downstream USGS monitoring site on the Tongue River before the confluence with the Yellowstone River. USGS reports a bankfull width of 147 feet and a mean bankfull depth of 4.8 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 1002. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-61.

Figure B-61. Tongue River at Miles City, Montana (USGS Gage 06308500). Photos by USGS.

B.6.1 Hydrologic Calibration

Discharge data are available for the Tongue River at Miles City, Montana at USGS gage 06308500. The period of record at this gage is 1938 to present; the record is 100 percent complete between 1946 and present. The six-year period between October 1, 2000 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The Tongue River Reservoir was rehabilitated between 1996 and 1999, raising the storage capacity from 68,000 to 79,000 acre-feet (DNRC, 2005). The LSPC model cannot account for varying dam heights or storage volumes; therefore, LSPC was only setup for post-rehabilitation conditions. The first full year of normal operation after the rehabilitation was 2000.
- The entire period between October 1, 2000 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal and dry years, but does not include wet years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-62, Figure B-63, Figure B-64, Figure B-65, and Table B-11.

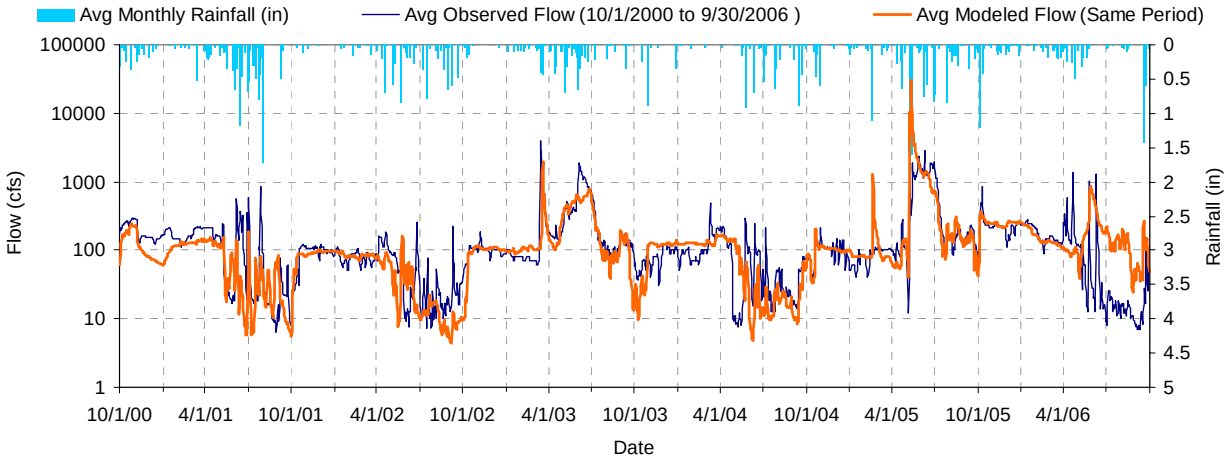

Figure B-62. Time series hydrologic calibration results (daily mean) for Tongue River at Miles City, Montana (USGS Gage 06308500).

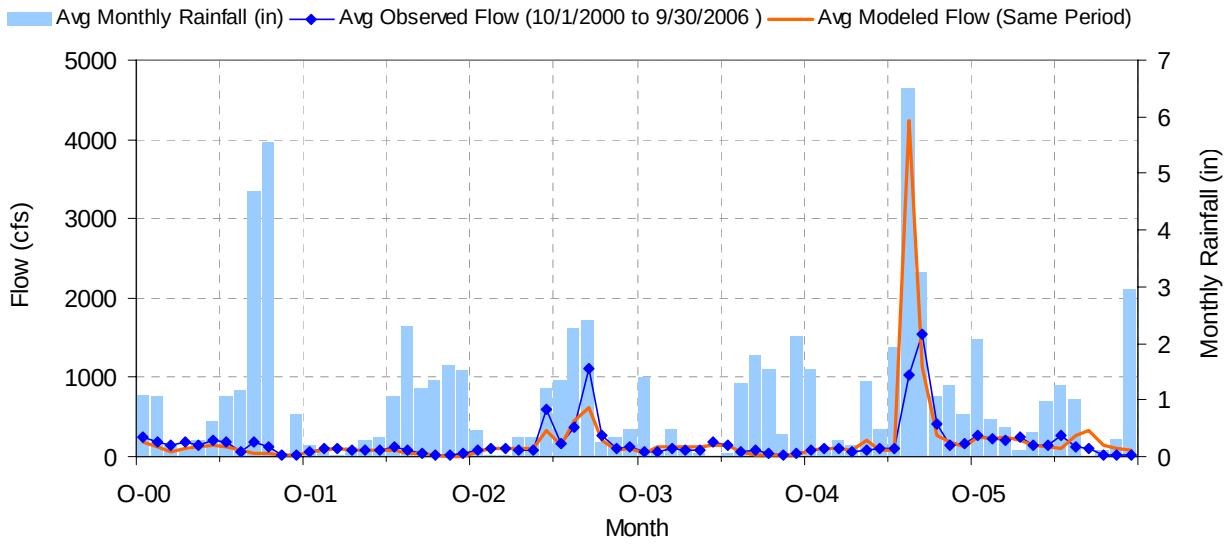

Figure B-63. Time series hydrologic calibration results (monthly mean) for Tongue River at Miles City, Montana (USGS Gage 06308500).

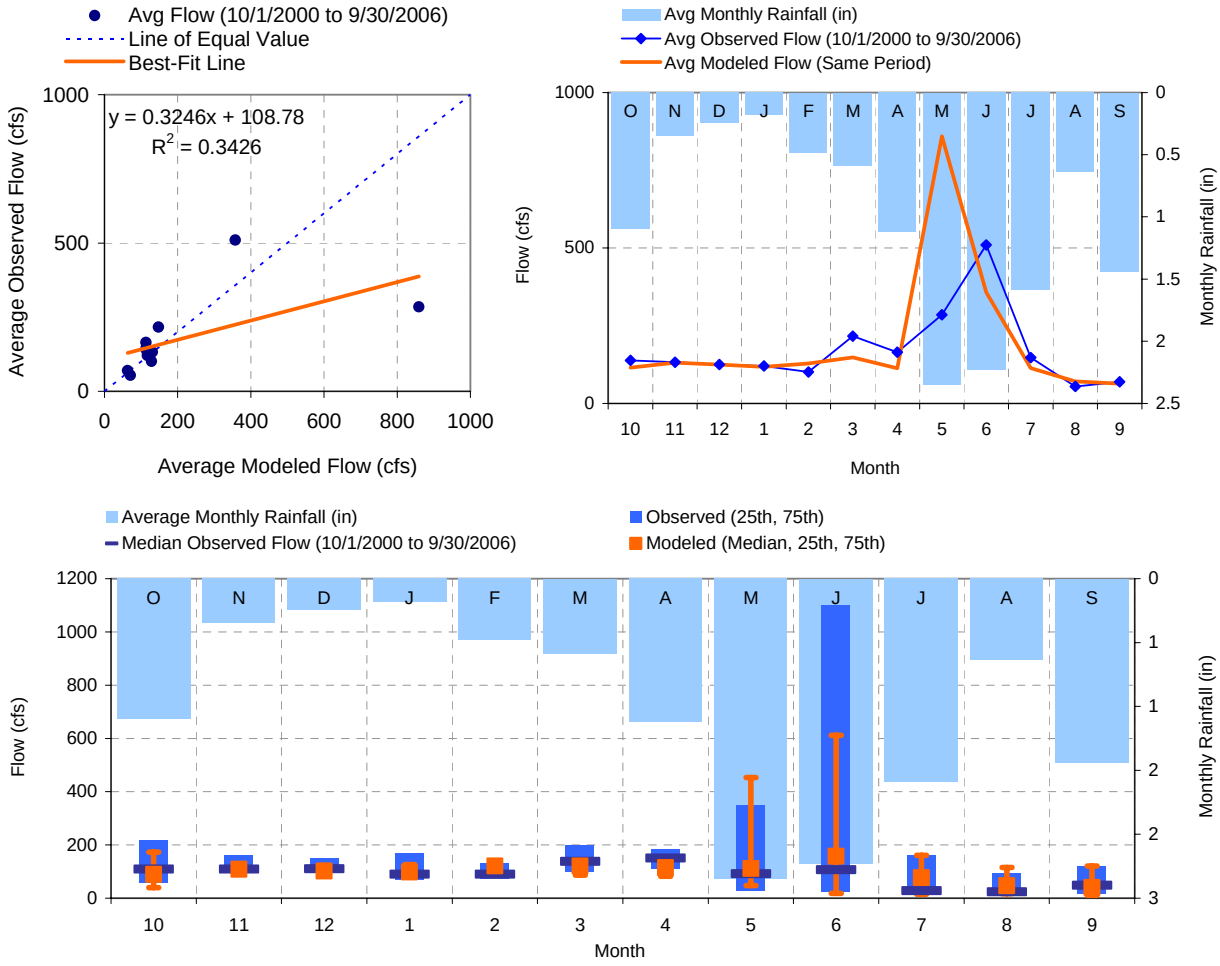

Figure B-64. Composite (average monthly) hydrologic calibration results for Tongue River at Miles City, Montana (October 1, 2000 to September 30, 2006).

Table B-11. Hydrologic calibration statistics for Tongue River at Miles City, Montana (USGS Gage 06308500) (October 1, 2000 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	852,257	102	196	748,338	100	172	13.9%	2.2%	13.9%
Growing Season	672,978	91	231	576,532	102	198	16.7%	-11.3%	16.7%
Non-growing Season	179,279	107	125	171,806	100	120	4.3%	7.2%	4.3%
January	43,229	98	117	44,579	90	121	-3.0%	8.4%	-3.0%
February	43,129	121	129	33,957	90	101	27.0%	34.1%	27.0%
March	54,539	120	148	79,904	138	217	-31.7%	-12.7%	-31.7%
April	40,445	115	113	58,785	151	165	-31.2%	-23.8%	-31.2%
May	316,892	111	859	105,154	92	285	201.4%	21.8%	201.4%
June	127,716	157	358	182,089	107	510	-29.9%	47.2%	-29.9%
July	42,040	77	114	54,335	28	147	-22.6%	173.5%	-22.6%
August	26,294	47	71	20,072	24	54	31.0%	94.2%	31.0%
September	22,629	41	63	24,975	49	70	-9.4%	-16.4%	-9.4%
October	42,421	90	115	51,218	109	139	-17.2%	-17.9%	-17.2%
November	46,754	109	131	47,250	109	132	-1.0%	-0.3%	-1.0%
December	46,166	101	125	46,020	110	125	0.3%	-7.8%	0.3%
10% Highest Flows	847,786	109	217	742,606	109	187	14.2%	-0.3%	15.7%
10% Lowest Flows	4,440	10	10	5,732	22	36	-22.5%	-53.1%	-71.8%

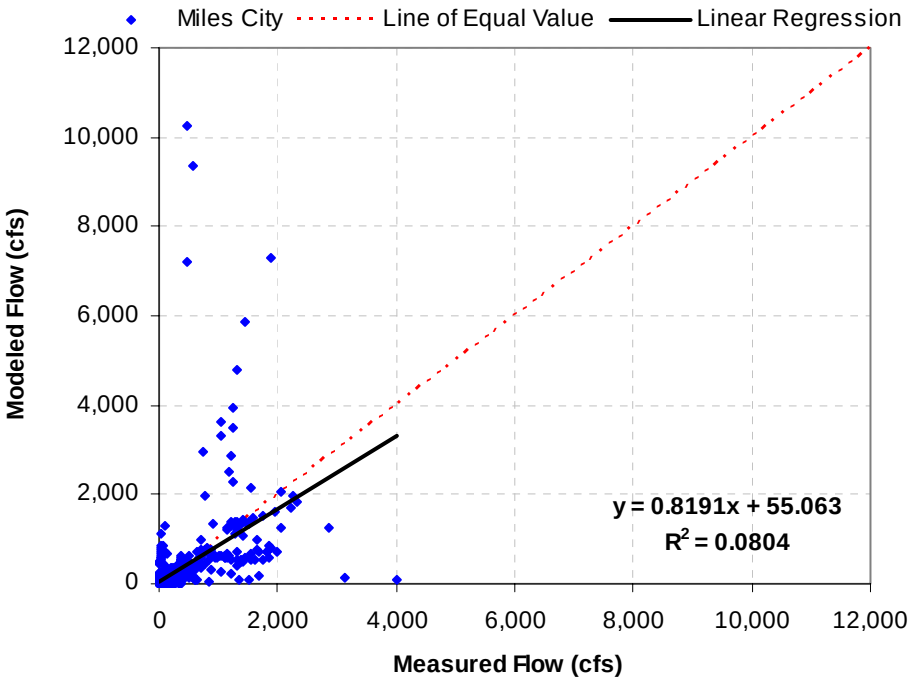

Figure B-65. Observed versus simulated scatter plot of average daily values for the Tongue River at Miles City, Montana (October 1, 2000 to September 30, 2006).

B.6.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in the Tongue River to supplement the water quality impairment analysis for salinity and sodium adsorption ratio (SAR) (as described in the Assessment Report, DEQ, 2005). Data were collected at USGS Gage 06308500 (Tongue River at Miles City, Montana) at varying frequencies from 1959 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration.

B.6.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for the Tongue River at Miles City at USGS Gage 06308500. The period of record at this gage for salinity is 1959 to present. During this period, samples were collected at varying frequencies. Daily data were collected from April 29, 2004 to present. The daily data collected between May 1, 2004 and September 30, 2006 were used for the salinity calibration. This time period provided 2.5 years of nearly continuous SC data with which to calibrate the LSPC model (n=786, 89 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-66, Figure B-67, Figure B-68, Figure B-69, Figure B-70, and Table B-12.

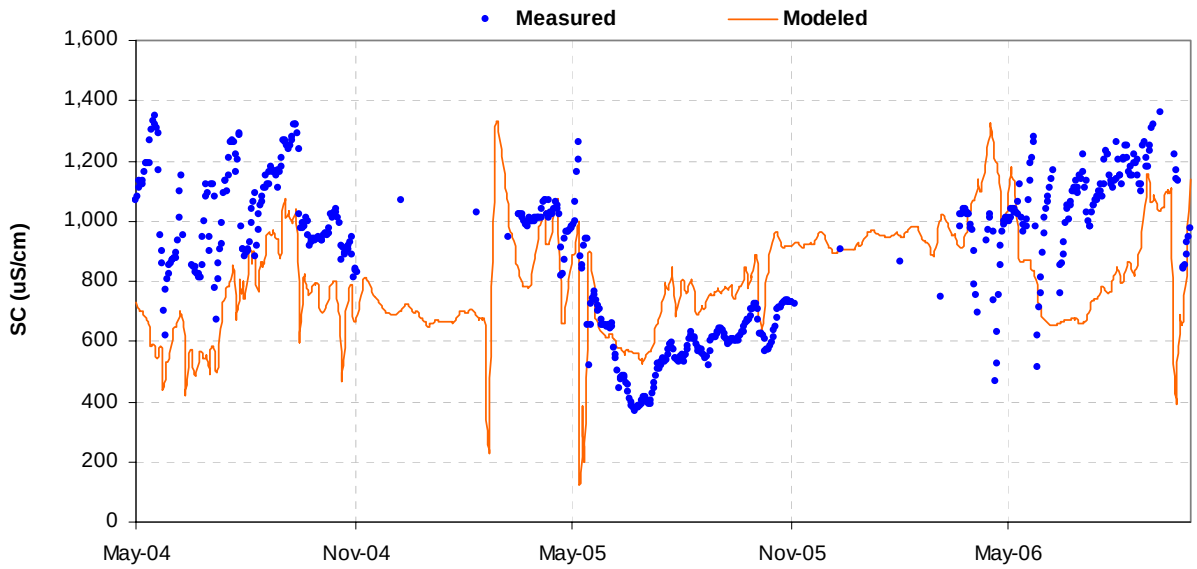

Figure B-66. Time series of salinity data for the Tongue River at Miles City, Montana (USGS Gage 06308500).

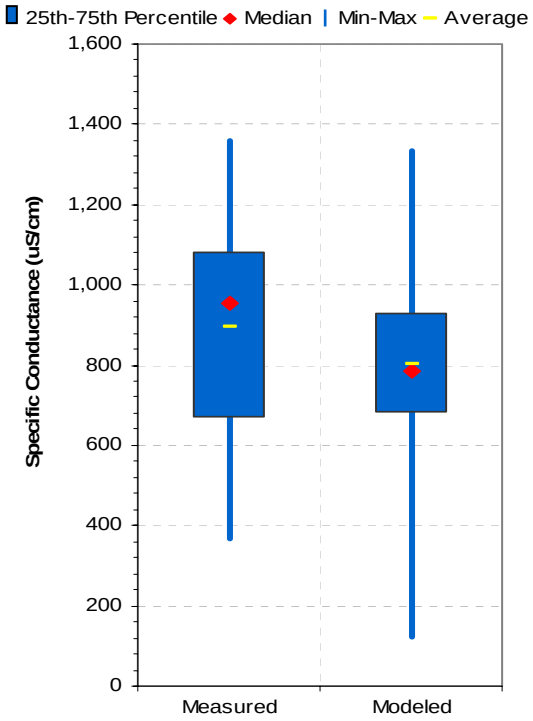

Figure B-67. Distribution of measured and modeled salinity data for the Tongue River at Miles City, Montana (May 1, 2004 to September 30, 2006).

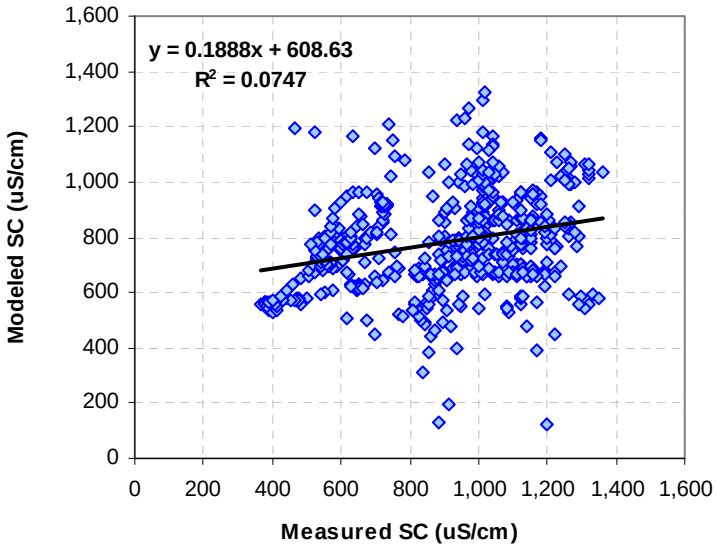

Figure B-68. Observed versus simulated scatter plot of average daily salinity values for the Tongue River at Miles City, Montana (May 1, 2004 to September 30, 2006).

Table B-12. Salinity calibration statistics for Tongue River at Miles City, Montana. (May 1, 2004 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)
All Data	773	778	955	897	-19.0%	-13.3%
Growing Season	773	778	955	897	-19.0%	-13.3%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	881	888	1,010	997	-12.7%	-11.0%
April	1,006	995	981	937	2.6%	6.2%
May	693	720	983	957	-29.5%	-24.8%
June	604	607	853	786	-29.2%	-22.8%
July	740	713	998	892	-25.8%	-20.1%
August	840	855	1,095	947	-23.3%	-9.7%
September	784	817	929	896	-15.6%	-8.9%
October	783	784	773	805	1.2%	-2.6%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in the Tongue River at Miles City (USGS Gage 06308500). Months with less than 15 observed samples were excluded from this analysis.**

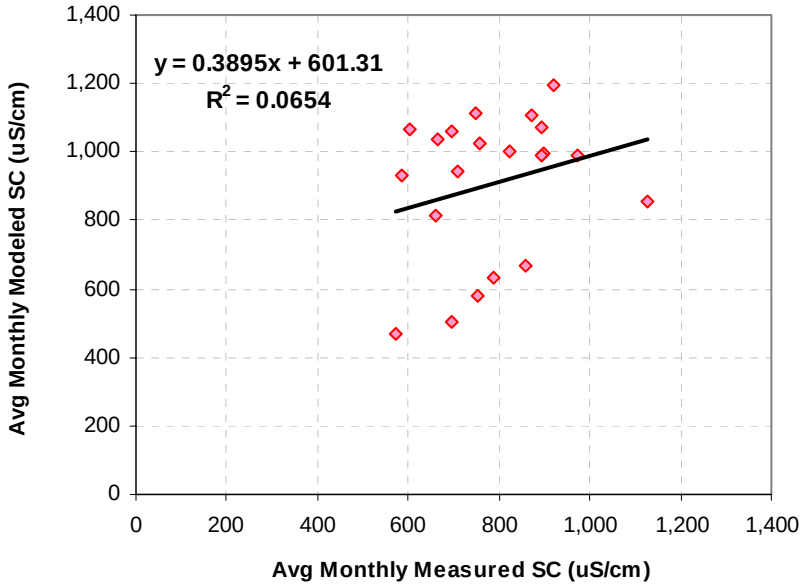

Figure B-69. Observed versus simulated scatter plot of average monthly salinity values for the Tongue River at Miles City, Montana (May 1, 2004 to September 30, 2006).

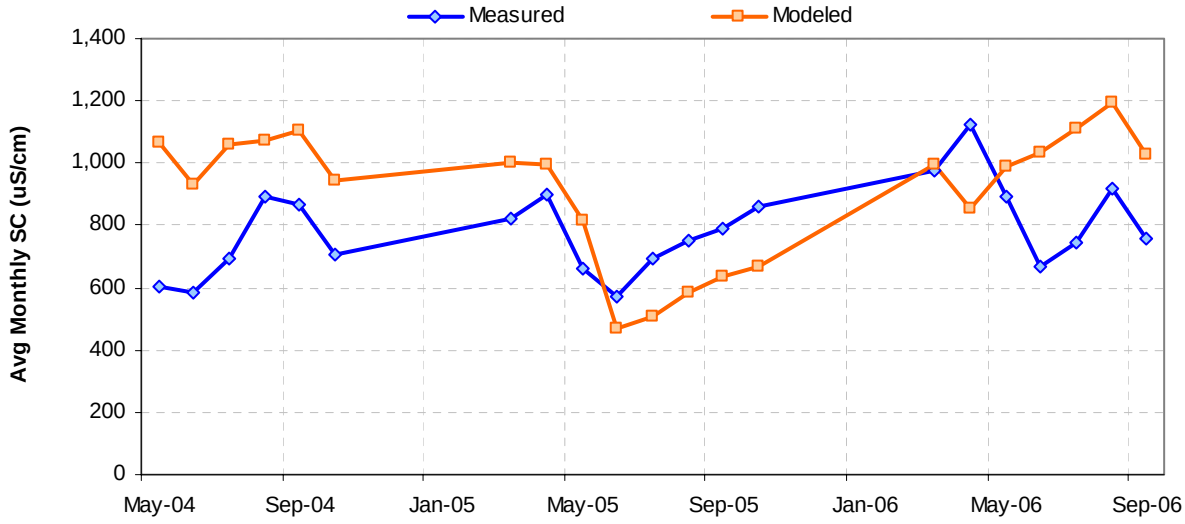

Figure B-70. Time series of average monthly salinity data for the Tongue River at Miles City, Montana (USGS gage 06308500).

B.6.2.2 SAR

SAR data are available for the Tongue River at Miles City at USGS Gage 06308500. The period of record at this gage for SAR is 1959 to present. During this period, samples were collected at varying frequencies. Daily data were collected from April 29, 2004 to present. The data collected between May 1, 2004 and September 30, 2006 were used for the SAR calibration. This time period provided 2.5 years of nearly continuous SAR data with which to calibrate the LSPC model (n=577, 65 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-71, Figure B-72, Figure B-73, Figure B-74, Figure B-75, and Table B-13.

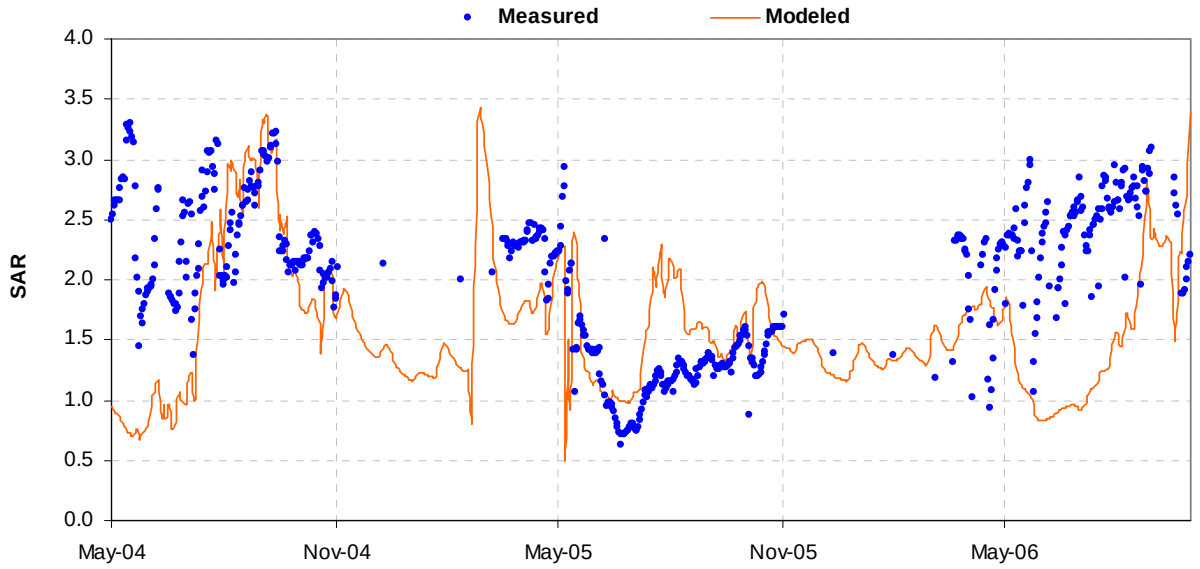

Figure B-71. Times series of continuous SAR data for the Tongue River at Miles City, Montana (USGS Gage 06308500).

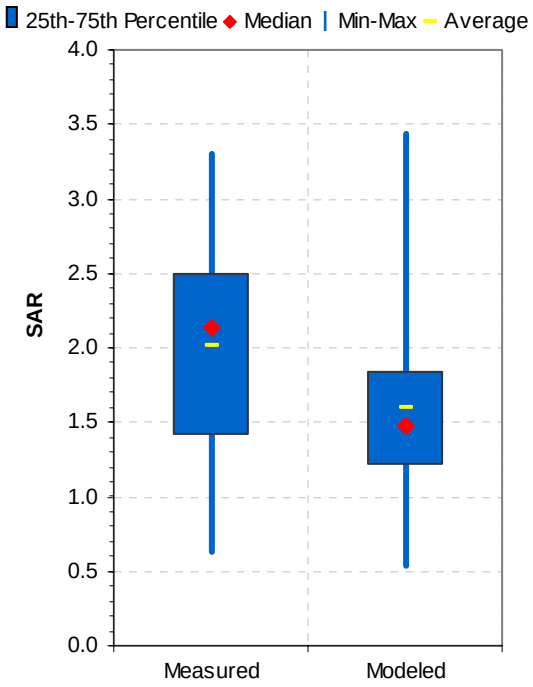

Figure B-72. Distribution of measured and modeled SAR data for the Tongue River at Miles City, Montana (May 1, 2004 to September 30, 2006).

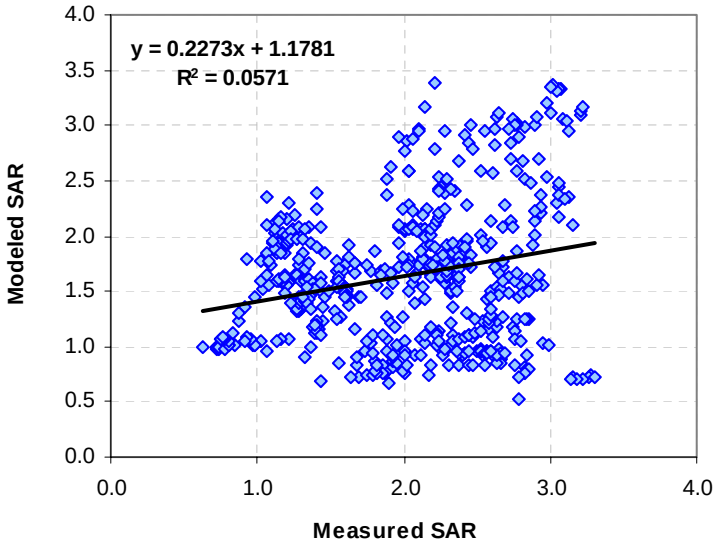

Figure B-73. Observed versus simulated scatter plot of average daily SAR values for the Tongue River at Miles City, Montana (May 1, 2004 to September 30, 2006).

Table B-13. SAR calibration statistics for Tongue River at Miles City, Montana. (May 1, 2004 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SAR	Average SAR	Median SAR	Average SAR	Median SAR	Average SAR
All Data	1.61	1.62	2.14	2.01	-24.9%	-19.4%
Growing Season	1.61	1.62	2.14	2.01	-24.9%	-19.4%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	1.65	1.67	2.30	2.22	-28.2%	-25.0%
April	1.79	1.80	2.24	2.10	-19.9%	-14.1%
May	1.09	1.20	2.23	2.18	-51.2%	-44.8%
June	0.98	0.98	1.89	1.75	-47.9%	-44.1%
July	1.45	1.56	2.25	2.01	-35.5%	-22.5%
August	2.07	2.18	2.47	2.14	-16.1%	2.0%
September	1.87	2.06	1.82	1.98	2.9%	4.2%
October	1.75	1.74	1.69	1.78	3.7%	-2.3%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in the Tongue River at Miles City (USGS Gage 06308500). Months with less than 15 observed samples were excluded from this analysis.**

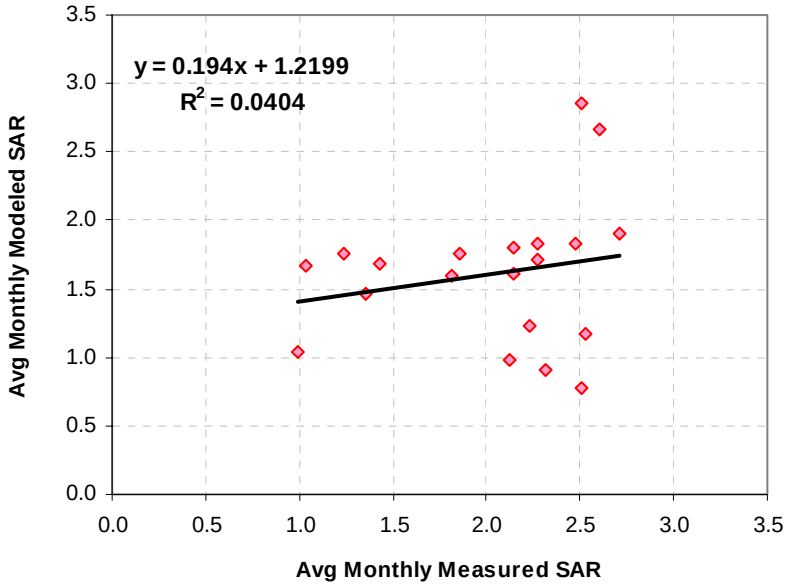

Figure B-74. Observed versus simulated scatter plot of average monthly SAR values for the Tongue River at Miles City, Montana. (May 1, 2004 to September 30, 2006).

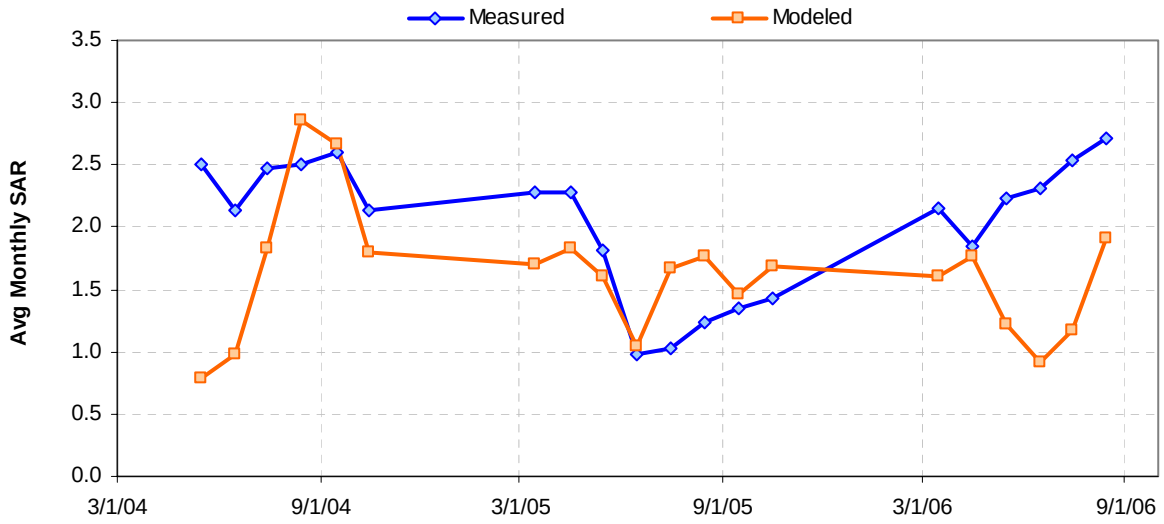

Figure B-75. Time series of average monthly salinity data for the Tongue River at Miles City, Montana. (USGS gage 06308500).

B.7 Hanging Woman Creek near Birney, MT

USGS gaging station 06307600 (Hanging Woman Creek near Birney, Montana) is located at latitude 45.29555º, longitude -106.50393º (NAD83) in Rosebud County, Montana, Hydrologic Unit 10090102 (USGS, 2004). The gage elevation is 3,150 feet (NGVD 29), and the gage has a watershed area of 470 square miles. USGS reports a bankfull width of 6.0 feet and a mean bankfull depth of 0.7 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 1095. The location of the gage is shown in Figure B-1 and a photo of the location is shown in Figure B-76.

Figure B-76. Hanging Woman Creek near Birney, Montana (USGS Gage 06307600). Photo by USGS.

B.7.1 Hydrologic Calibration

Discharge data are available for Hanging Woman Creek near Birney, Montana at USGS gage 06307600. The period of record for flow is from 1973 to 1995, and 2003 to present. The five-year period between October 1, 1990 and September 30, 1995 was selected for calibration at this location. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between October 1, 1990 and September 30, 1995 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal and wet years, but not dry years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-77, Figure B-78 Figure B-79, Figure B-80, and Table B-14.

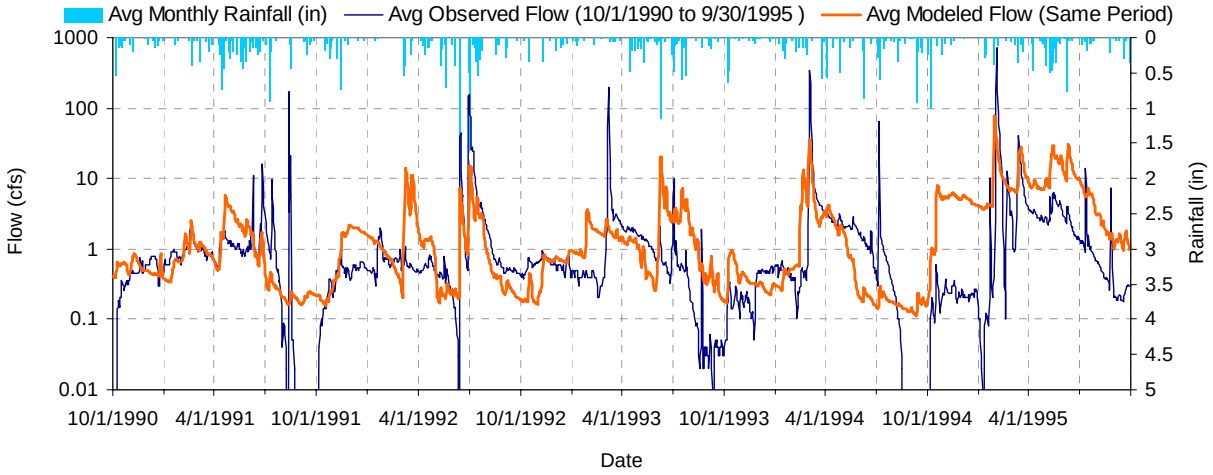

Figure B-77. Time series of hydrologic calibration results (daily mean) for Hanging Woman Creek near Birney, Montana (USGS Gage 06307600).

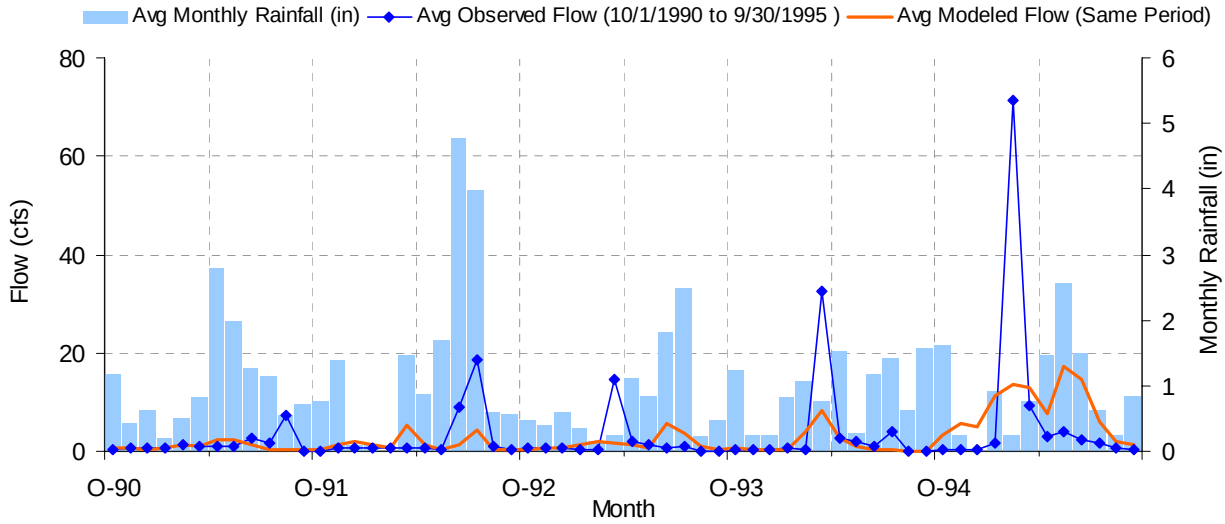

Figure B-78. Time series of hydrologic calibration results (monthly mean) for Hanging Woman Creek near Birney, Montana (USGS Gage 06307600).

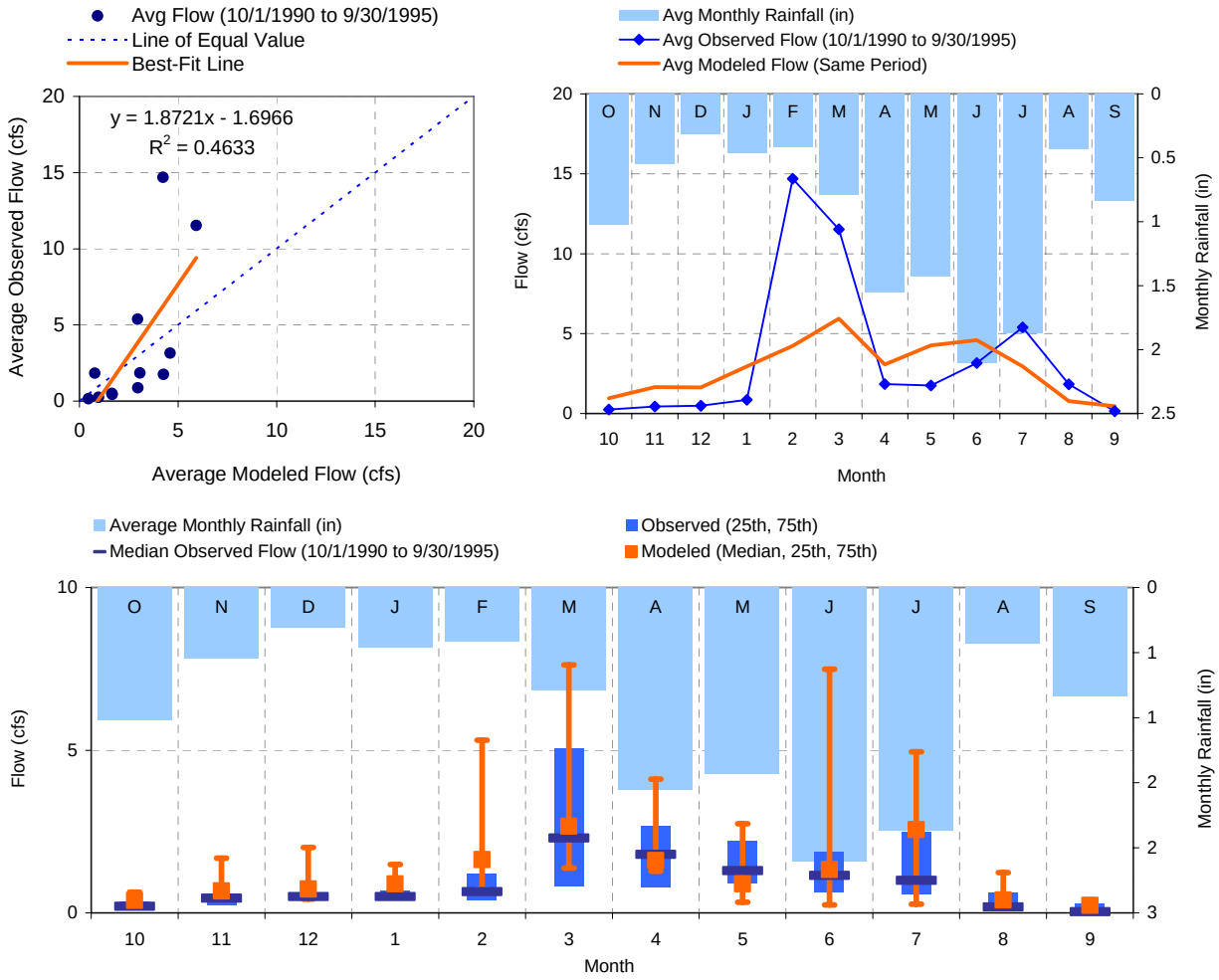

Figure B-79. Composite (average monthly) hydrologic calibration results for Hanging Woman Creek near Birney, Montana (USGS Gage 06307600) (October 1, 1990 to September 30, 1995).

Table B-14. Hydrologic calibration statistics for Hanging Woman Creek near Birney, Montana, USGS Gage 06307600 (October 1, 1990 to September 30, 1995).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	10,088	0.9	2.8	12,565	0.6	3.5	-20%	55%	-20%
Growing Season	6,993	1.0	2.9	7,911	0.7	3.3	-12%	42%	-12%
Non-growing Season	3,095	0.8	2.6	4,654	0.5	3.9	-34%	66%	-34%
January	910	0.9	3.0	265	0.5	0.9	243%	78%	243%
February	1,186	1.6	4.2	4,108	0.7	14.7	-71%	152%	-71%
March	1,822	2.7	5.9	3,545	2.3	11.5	-49%	16%	-49%
April	915	1.6	3.1	548	1.8	1.8	67%	-11%	67%
May	1,310	0.9	4.3	540	1.3	1.8	143%	-32%	143%
June	1,367	1.3	4.6	938	1.2	3.2	46%	16%	46%
July	909	2.6	3.0	1,654	1.0	5.4	-45%	156%	-45%
August	240	0.4	0.8	564	0.2	1.8	-58%	123%	-58%
September	135	0.2	0.5	45	0.0	0.2	202%	570%	202%
October	297	0.4	1.0	78	0.2	0.3	280%	93%	280%
November	494	0.7	1.7	131	0.5	0.4	278%	50%	278%
December	506	0.7	1.6	150	0.5	0.5	236%	46%	236%
10% Highest Flows	10,026	1.1	3.1	12,559	0.6	3.7	-20%	90%	-16%
10% Lowest Flows	62	0.2	0.2	6	0.1	1.7	1002%	74%	-90%

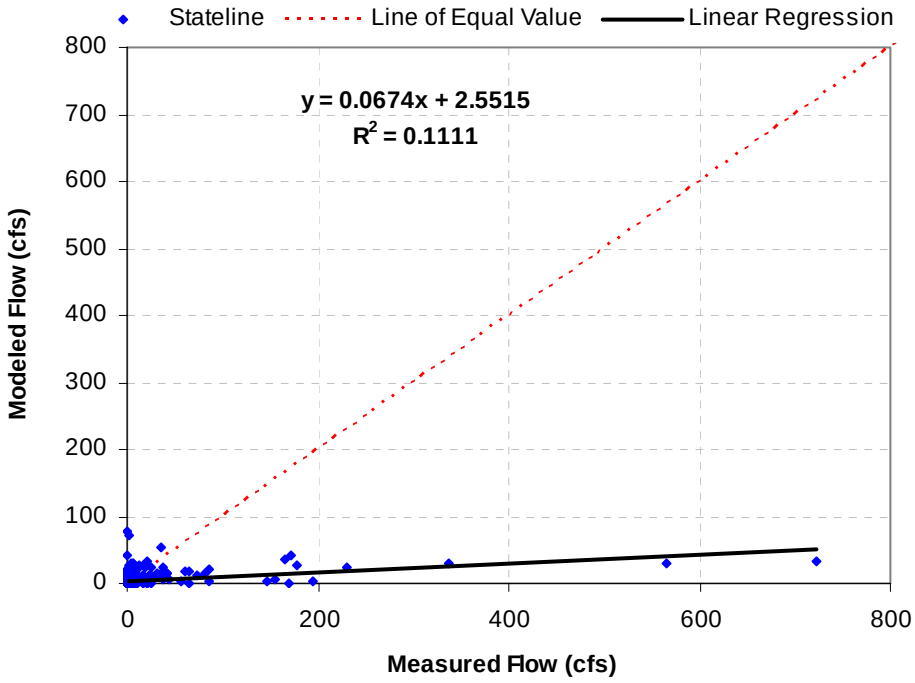

Figure B-80. Observed versus simulated scatter plot of average daily values for Hanging Woman Creek near Birney, Montana (October 1, 1990 to September 30, 1995).

B.7.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in Hanging Woman Creek to supplement the water quality impairment analysis for salinity and sodium adsorption ratio (SAR) (as described in the Assessment Report; USEPA, 2007). Data were collected at USGS Gage 06307600 (Hanging Woman Creek near Birney, Montana) at varying frequencies from 1974 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration for Hanging Woman Creek.

B.7.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for Hanging Woman Creek at USGS Gage 06307600. The period of record at this gage for salinity is 1974 to present. During this period, samples were collected at varying frequencies. Daily data were collected from November 1, 1980 to September 30, 1987, and from May 22, 2004 to June 16, 2006. The data collected between October 1, 2003 and September 30, 2006 were used for the salinity calibration. This time period provided 3 years of salinity data with some continuous daily data (n=249, 33 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-81, Figure B-82, Figure B-83, Figure B-84, Figure B-85, and Table B-15.

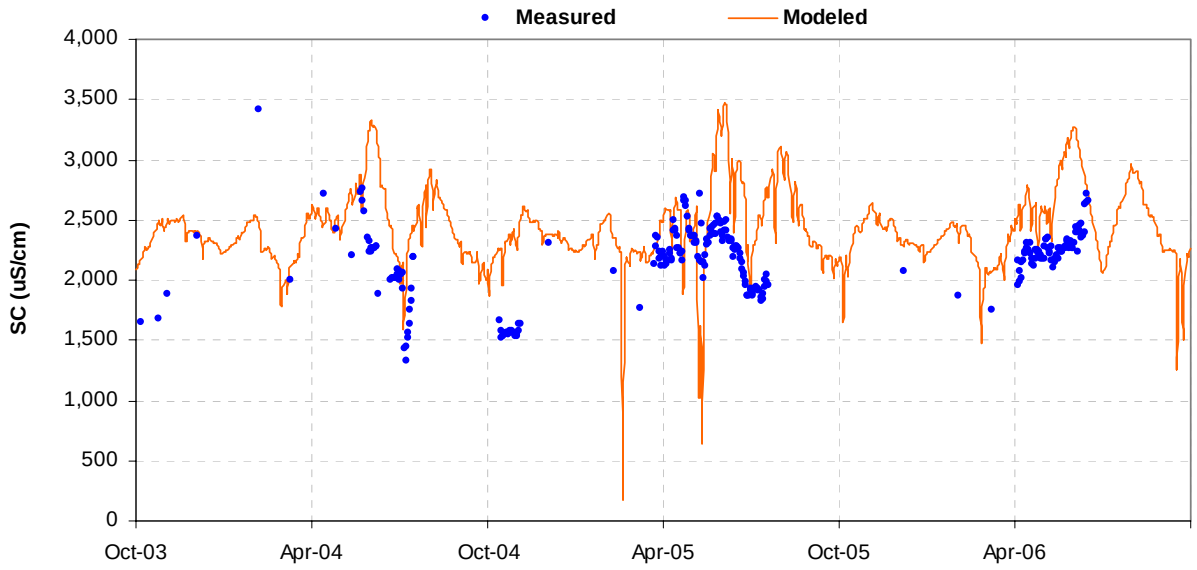

Figure B-81. Time series of salinity data for Hanging Woman Creek near Birney, Montana (USGS Gage 06307600).

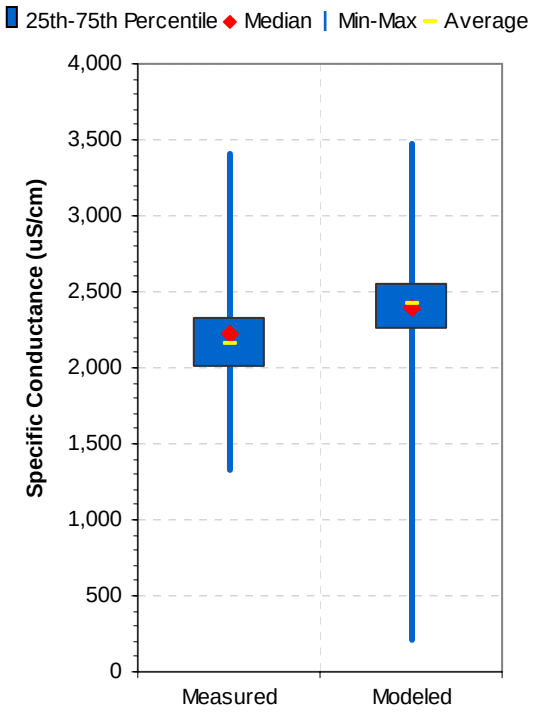

Figure B-82. Distribution of measured and modeled salinity data for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

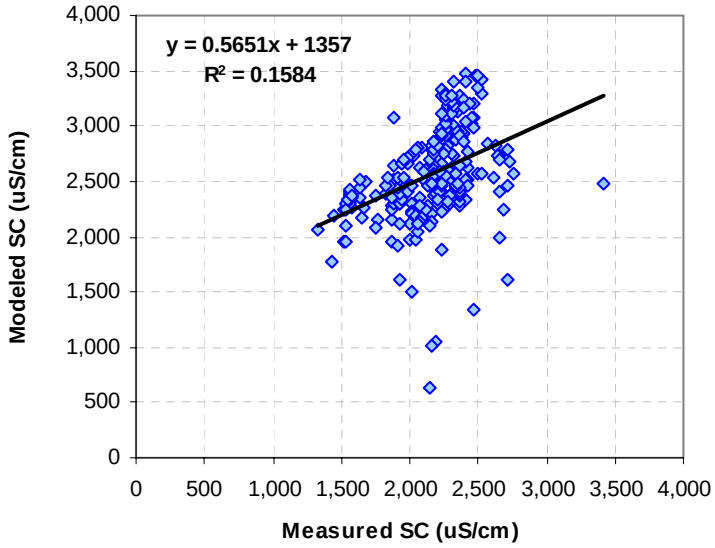

Figure B-83. Observed versus simulated scatter plot of average daily salinity values for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

Table B-15. Salinity calibration statistics for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (%)	Average SC (%)
All Data	2,571	2,587	2,220	2,151	15.8%	20.3%
Growing Season	2,571	2,587	2,220	2,151	15.8%	20.3%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA
April	2,568	2,503	2,230	2,260	15.2%	10.8%
May	2,725	2,639	2,298	2,300	18.6%	14.7%
June	2,889	2,849	2,270	2,246	27.3%	26.9%
July	2,371	2,340	1,920	1,868	23.5%	25.3%
August	NA	NA	NA	NA	NA	NA
September	NA	NA	NA	NA	NA	NA
October	2,309	2,278	1,560	1,558	48.0%	46.2%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in Hanging Woman Creek near Birney, MT (USGS Gage 06307600). Months with less than 15 observed samples were excluded from this analysis.**

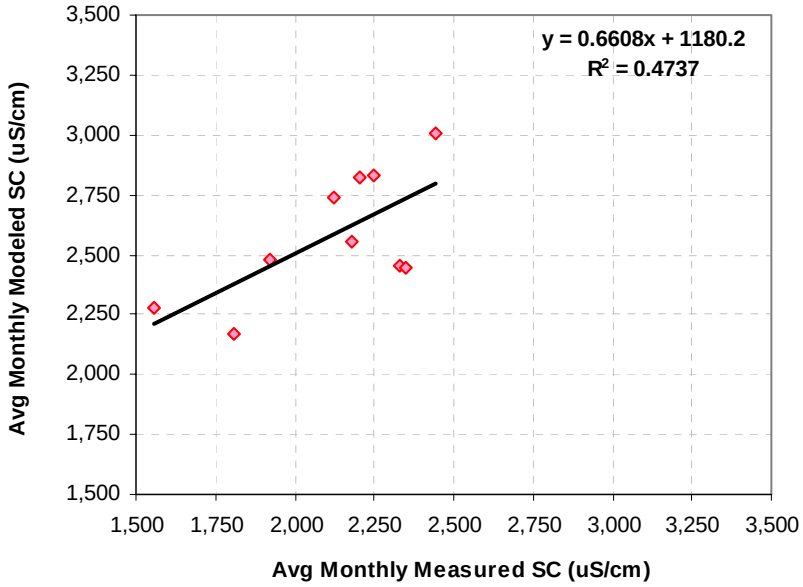

Figure B-84. Observed versus simulated scatter plot of average monthly salinity values for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

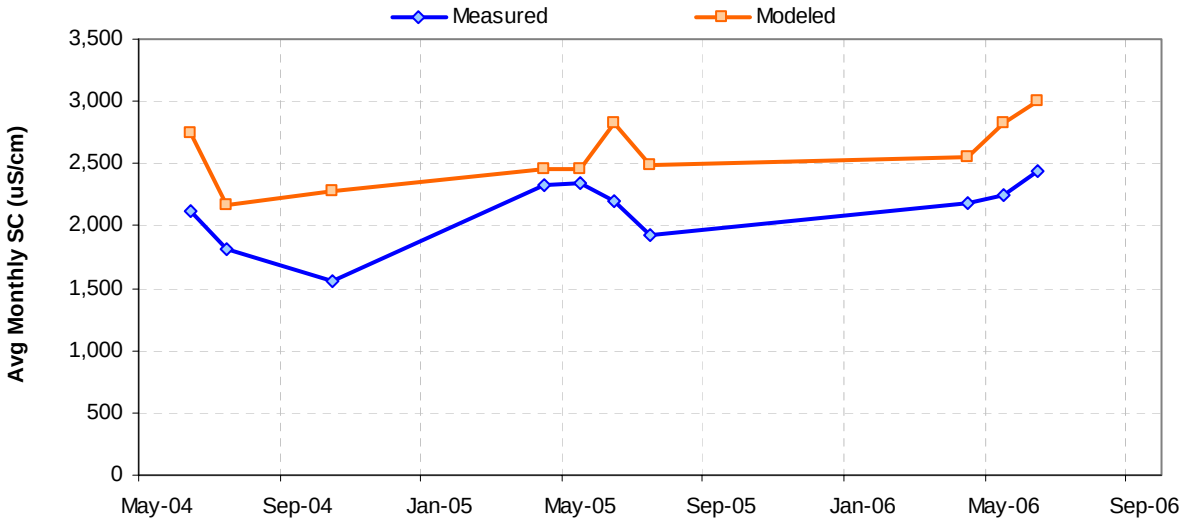

Figure B-85. Time series of average monthly salinity data for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

B.7.2.2 SAR

SAR data are available for Hanging Woman Creek at USGS Gage 06307600. The period of record at this gage for SAR is 1974 to present. During this period, samples were collected at varying frequencies. Daily data were collected from May 22, 2004 to June 16, 2006. The data collected between October 1, 2003 and September 30, 2006 were used for the SAR calibration. This time period provided 3 years of SAR data with some continuous daily data (n=228, 30 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-86, Figure B-87, Figure B-88, Figure B-89, Figure B-90, and Table B-16.

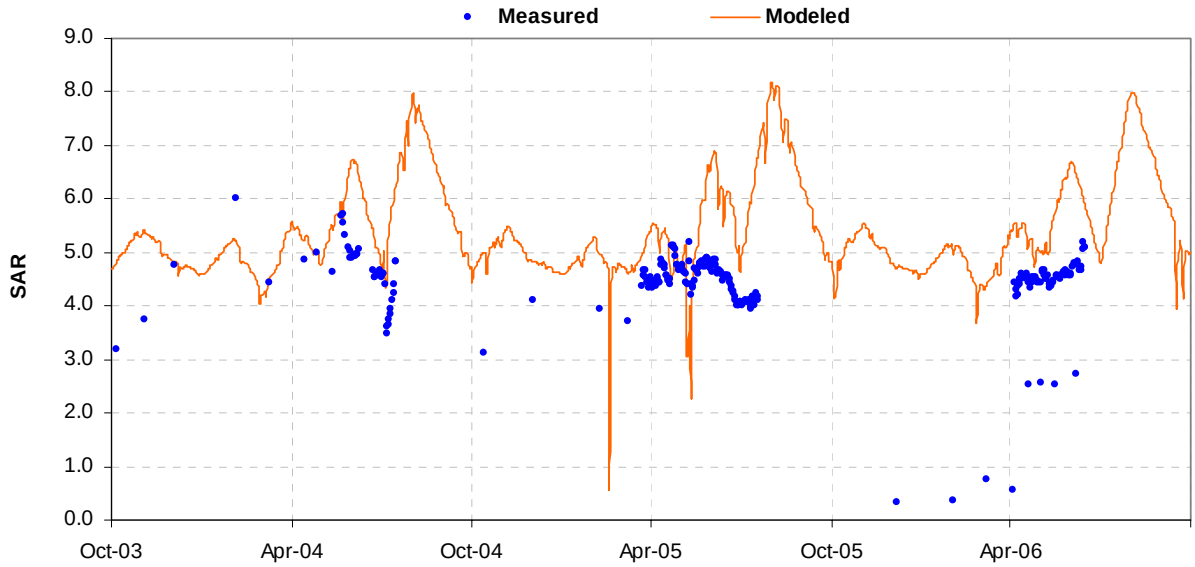

Figure B-86. Time series of SAR data for Hanging Woman Creek near Birney, Montana (USGS Gage 06307600).

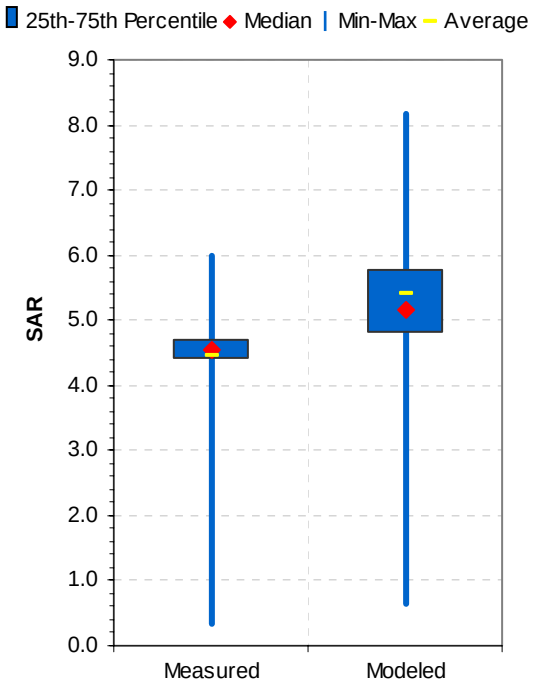

Figure B-87. Distribution of measured and modeled SAR data for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

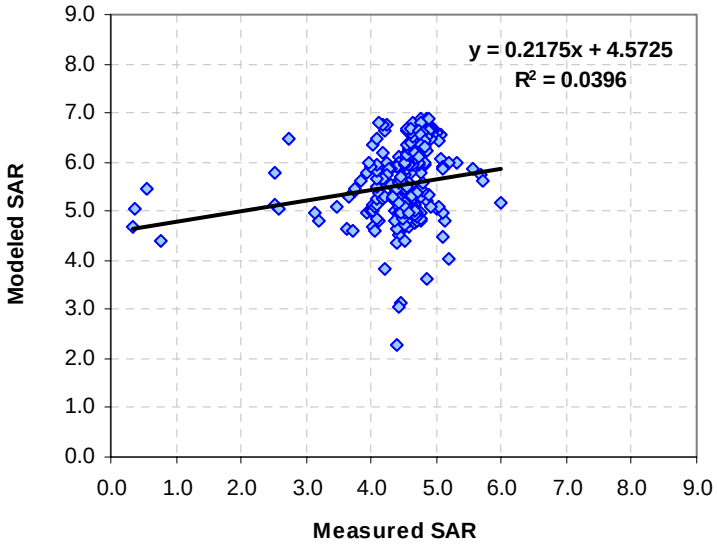

Figure B-88. Observed versus simulated scatter plot of average daily SAR values for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

Table B-16. SAR calibration statistics for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SAR	Average SAR	Median SAR	Average SAR	Median SAR	Average SAR
All Data	5.50	5.57	4.55	4.47	20.9%	24.6%
Growing Season	5.50	5.57	4.55	4.47	20.9%	24.6%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA
April	5.27	5.20	4.51	4.46	16.9%	16.8%
May	5.51	5.43	4.61	4.55	19.5%	19.4%
June	6.08	6.03	4.64	4.60	31.1%	31.0%
July	5.66	5.64	4.09	4.14	38.3%	36.1%
August	NA	NA	NA	NA	NA	NA
September	NA	NA	NA	NA	NA	NA
October	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in Hanging Woman Creek near Birney, MT (USGS Gage 06307600). Months with less than 15 observed samples were excluded from this analysis.**

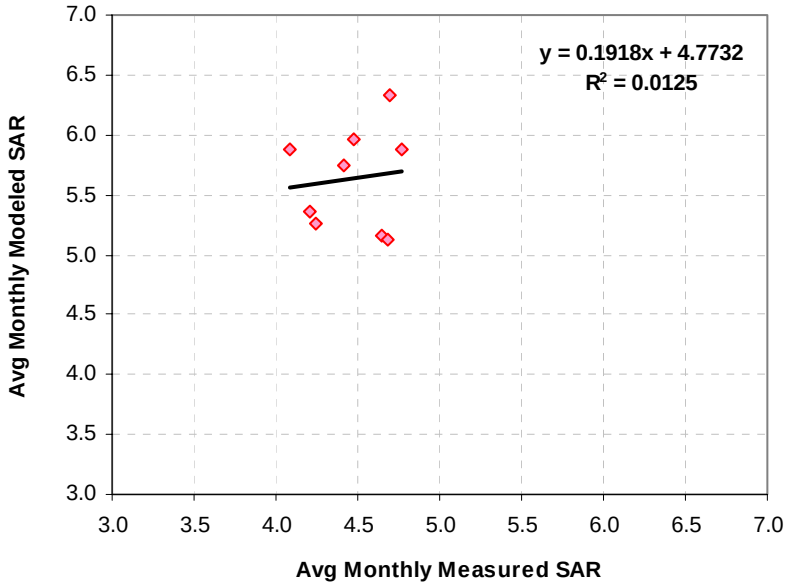

Figure B-89. Observed versus simulated scatter plot of average monthly SAR values for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

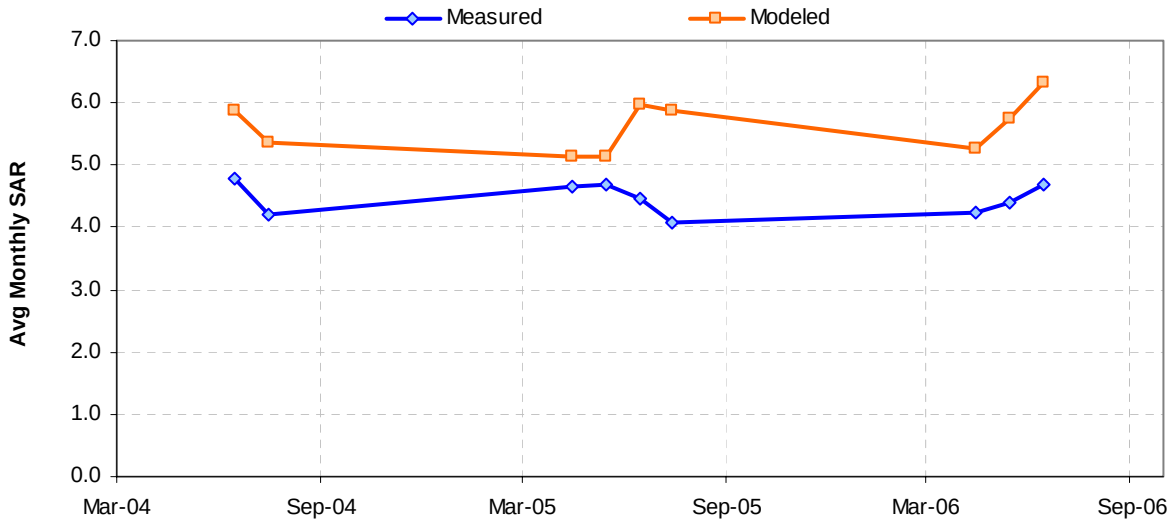

Figure B-90. Time series of average monthly salinity data for Hanging Woman Creek near Birney, Montana (October 1, 2003 to September 30, 2006).

B.8 Otter Creek at Ashland, MT

USGS gaging station 06307740 (Otter Creek at Ashland, Montana) is located at latitude 45.58389º, longitude -106.25529º (NAD83) in Rosebud County, Montana, Hydrologic Unit 10090102 (USGS, 2004). The gage elevation is 2,917 feet (NGVD 29), and the gage has a watershed area of 707 square miles. USGS reports a bankfull width of 22 feet and a mean bankfull depth of 1.1 feet (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 1059. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-91.

Figure B-91. Otter Creek at Ashland, Montana (USGS Gage 06307740). Photos by Tetra Tech, Inc and USGS.

B.8.1 Hydrologic Calibration

Discharge data are available for Otter Creek near Ashland, Montana at USGS gage 06307740. The period of record for flow is from 1972 to 1995, and 2003 to present. The five-year period between October 1, 1990 and September 30, 1995 was selected for calibration at this location. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1989 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between October 1, 1990 and September 30, 1995 was used for model calibration because of the dynamic nature of the Tongue River watershed. This period spans normal and wet years, but not dry years (see Section 4.1).

Daily and monthly average calibration graphs and statistics are provided in Figure B-92, Figure B-93, Figure B-94, Figure B-95, and Table B-17.

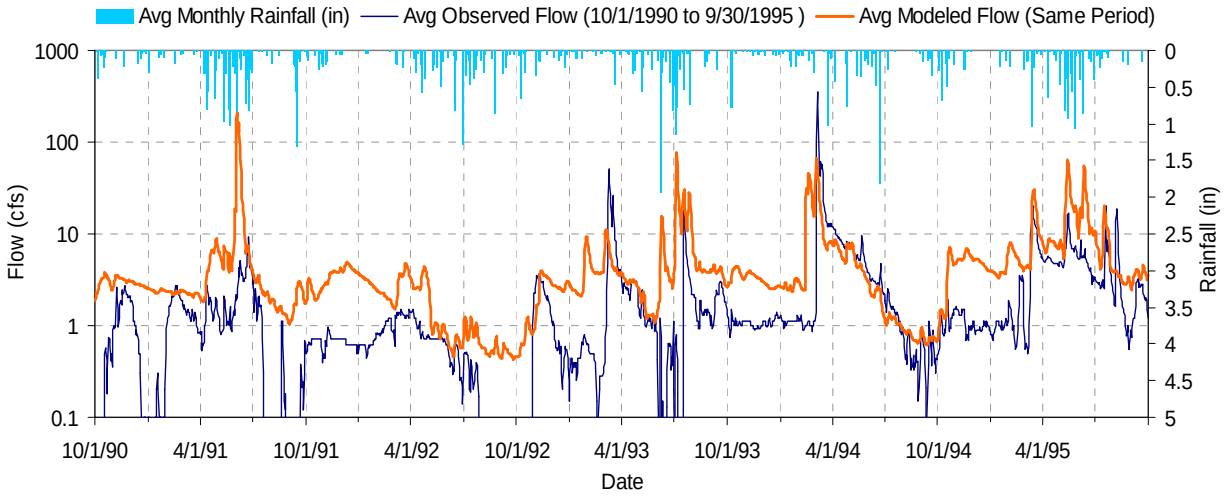

Figure B-92. Time series of hydrologic calibration results (daily mean) for Otter Creek at Ashland, Montana (USGS Gage 06307740).

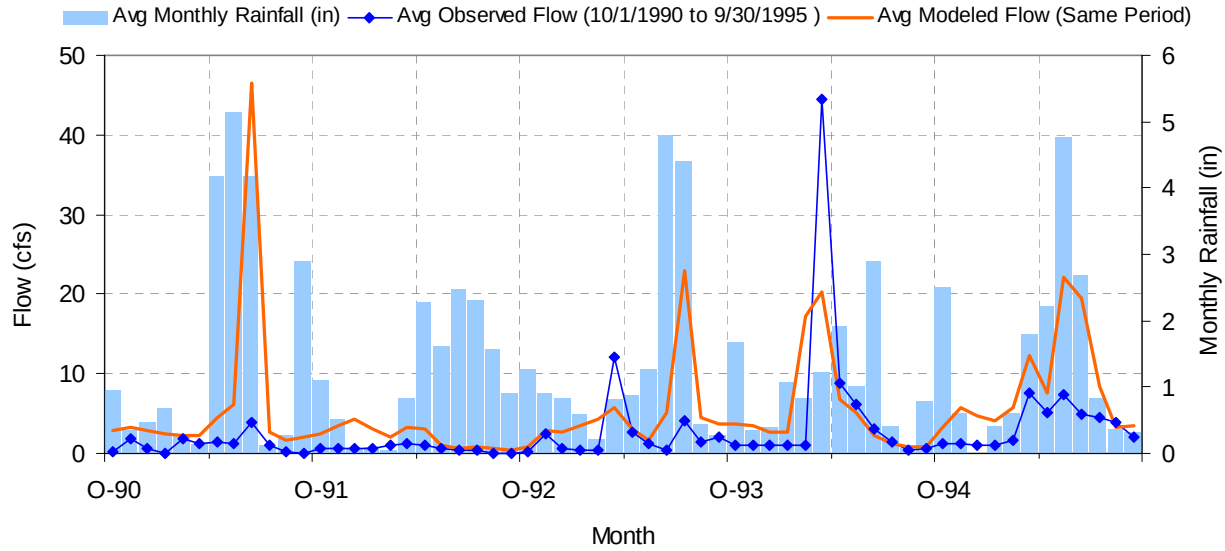

Figure B-93. Times series of hydrologic calibration results (monthly mean) for Otter Creek at Ashland, Montana (USGS Gage 06307740).

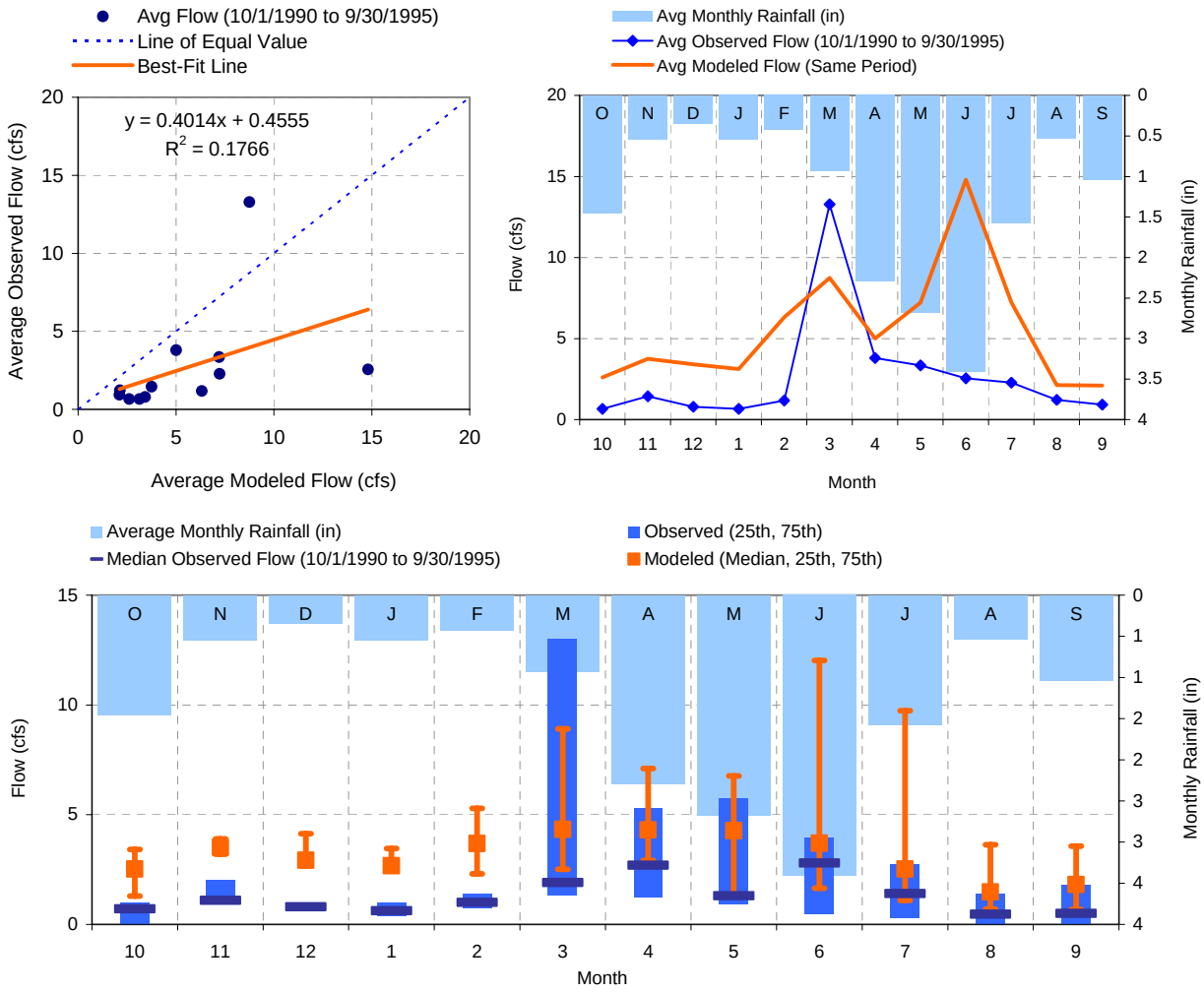

Figure B-94. Composite (average monthly) hydrologic calibration results for Otter Creek near Ashland, Montana (USGS Gage 06307740). (October 1, 1990 to September 30, 1995).

Table B-17. Hydrologic calibration statistics for Otter Creek at Ashland, Montana (USGS Gage 06307740) (October 1, 1990 to September 30, 1995).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	20,009	3.2	5.5	9,765	1.0	2.7	105%	216%	105%
Growing Season	15,111	3.1	6.2	8,560	1.2	3.5	77%	161%	77%
Non-growing Season	4,898	3.2	4.1	1,205	0.9	1.0	307%	243%	307%
January	962	2.7	3.1	202	0.6	0.7	376%	331%	376%
February	1,766	3.7	6.3	329	1.0	1.2	437%	268%	437%
March	2,688	4.3	8.7	4,084	1.9	13.3	-34%	128%	-34%
April	1,489	4.3	5.0	1,130	2.7	3.8	32%	60%	32%
May	2,217	4.3	7.2	1,029	1.3	3.3	115%	229%	115%
June	4,406	3.7	14.8	759	2.8	2.6	480%	32%	480%
July	2,221	2.5	7.2	703	1.4	2.3	216%	80%	216%
August	659	1.5	2.1	376	0.5	1.2	75%	216%	75%
September	628	1.8	2.1	276	0.5	0.9	128%	262%	128%
October	803	2.5	2.6	203	0.7	0.7	295%	256%	295%
November	1,118	3.5	3.8	431	1.1	1.4	159%	219%	159%
December	1,052	2.9	3.4	243	0.8	0.8	333%	266%	333%
10% Highest Flows	19,779	3.4	6.1	9,765	1.1	3.0	103%	209%	104%
10% Lowest Flows	230	0.6	0.6	0	0.2	0.3	115629%	NA	148%

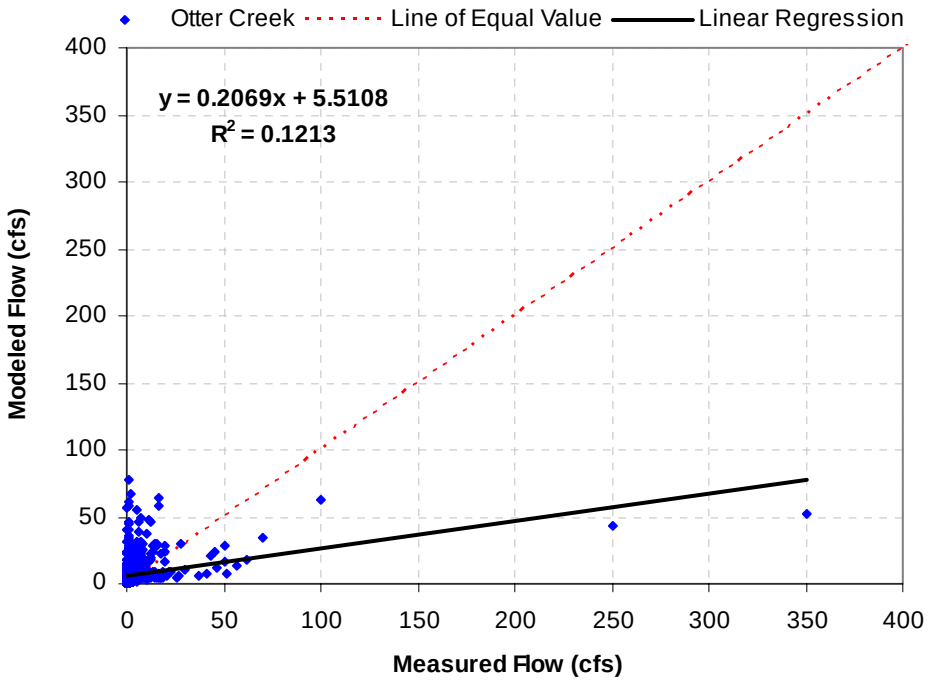

Figure B-95. Observed versus simulated scatter plot of average daily values for Otter Creek at Ashland, Montana (October 1, 1990 to September 30, 1995).

B.8.2 Water Quality Calibration

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in Otter Creek to supplement the water quality impairment analysis for salinity and sodium adsorption ratio (SAR) (as described in the Assessment Report, DEQ, 2005). Data were collected at USGS Gage 06307740 (Otter Creek at Ashland, Montana) at varying frequencies from 1974 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration for Otter Creek.

B.8.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for Otter Creek at USGS Gage 06307740. The period of record at this gage for salinity is 1974 to present. During this period, samples were collected at varying frequencies. Daily data were collected from November 1, 1980 to August 31, 1985, and from May 25, 2004 to present. The data collected between October 1, 2003 and September 30, 2006 were used for the salinity calibration. This time period provided 3 years of salinity data with some continuous daily data (n=484, 56 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-96, Figure B-97, Figure B-98, Figure B-99, Figure B-100, and Table B-18.

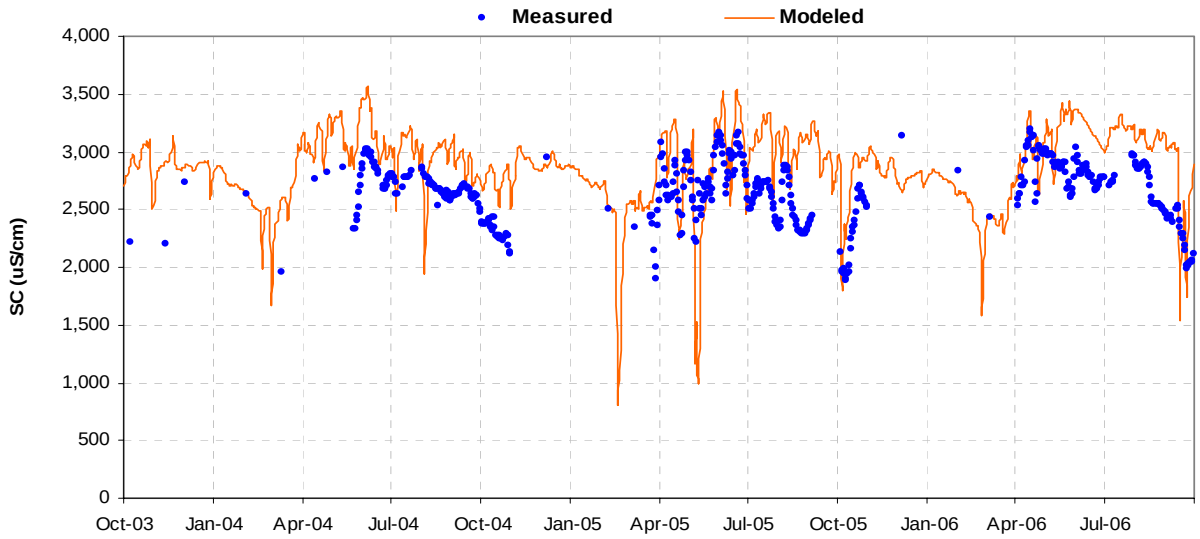

Figure B-96. Time series of salinity data for Otter Creek near Ashland, Montana (USGS Gage 06307740).

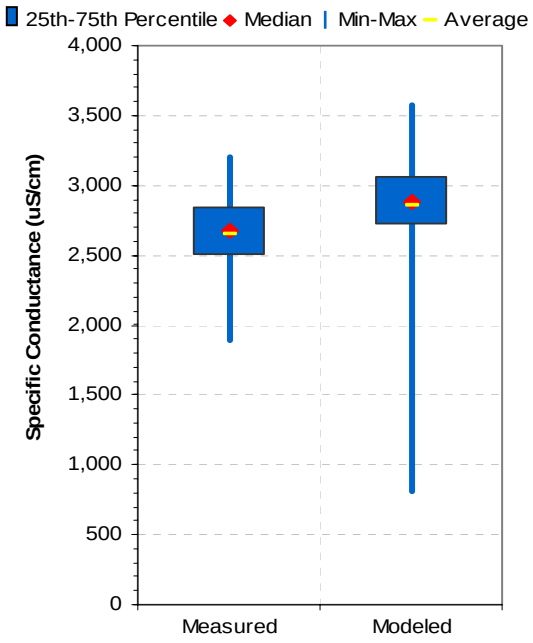

Figure B-97. Distribution of measured and modeled salinity data for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

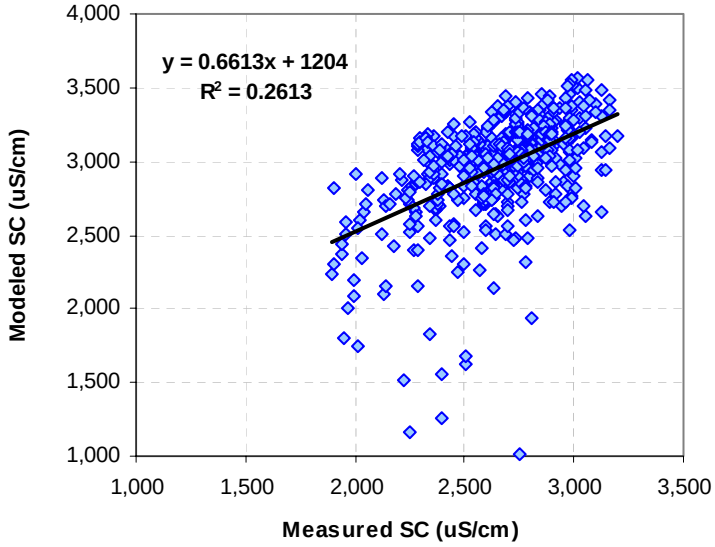

Figure B-98. Observed versus simulated scatter plot of average daily salinity values for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

Table B-18. Salinity calibration statistics for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (%)	Average SC (%)
All Data	3,029	2,965	2,690	2,668	12.6%	11.2%
Growing Season	3,029	2,965	2,690	2,668	12.6%	11.2%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA
April	2,978	2,960	2,760	2,799	7.9%	5.8%
May	3,072	2,865	2,795	2,772	9.9%	3.4%
June	3,178	3,170	2,855	2,873	11.3%	10.3%
July	3,102	3,061	2,700	2,669	14.9%	14.7%
August	3,060	3,027	2,650	2,631	15.5%	15.1%
September	2,855	2,757	2,500	2,459	14.2%	12.1%
October	2,815	2,781	2,340	2,348	20.3%	18.5%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in Otter Creek at Ashland, MT (USGS Gage 06307740). Months with less than 15 observed samples were excluded from this analysis.**

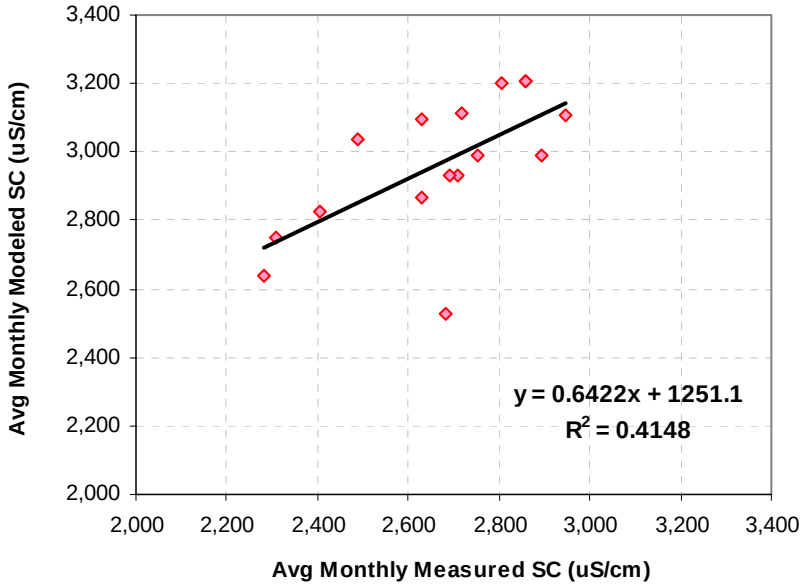

Figure B-99. Observed versus simulated scatter plot of average monthly salinity values for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

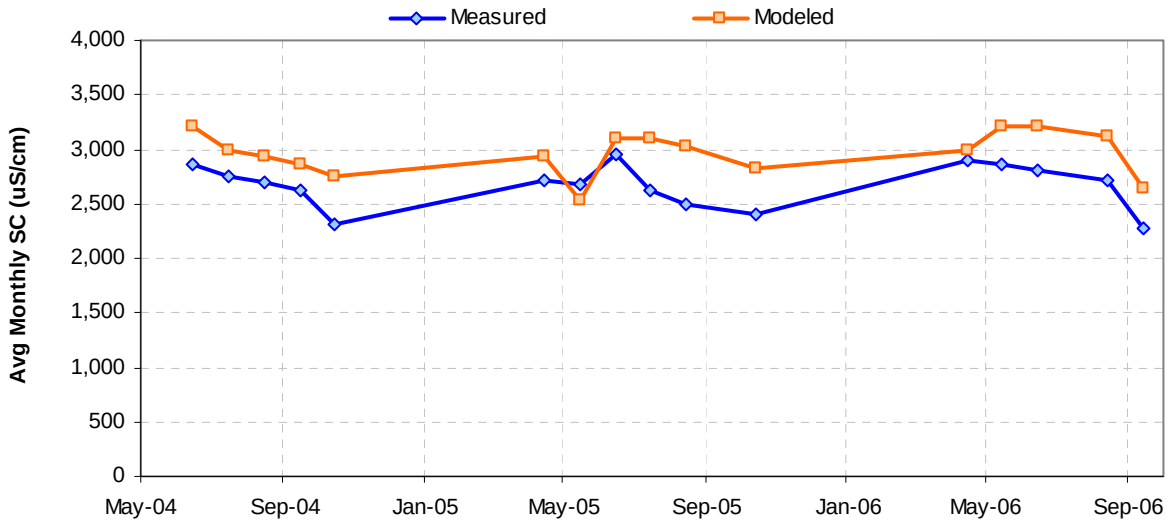

Figure B-100. Time series of average monthly salinity data for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

B.8.2.2 SAR

SAR data are available for Otter Creek at USGS Gage 06307740. The period of record at this gage for salinity is 1974 to present. During this period, samples were collected at varying frequencies. Daily data were collected from May 25, 2004 to present. The data collected between October 1, 2003 and September 30, 2006 were used for the SAR calibration. This time period provided 3 years of SAR data with some continuous daily data (n=513, 60 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-101, Figure B-102, Figure B-103, Figure B-104, Figure B-105, and Table B-19.

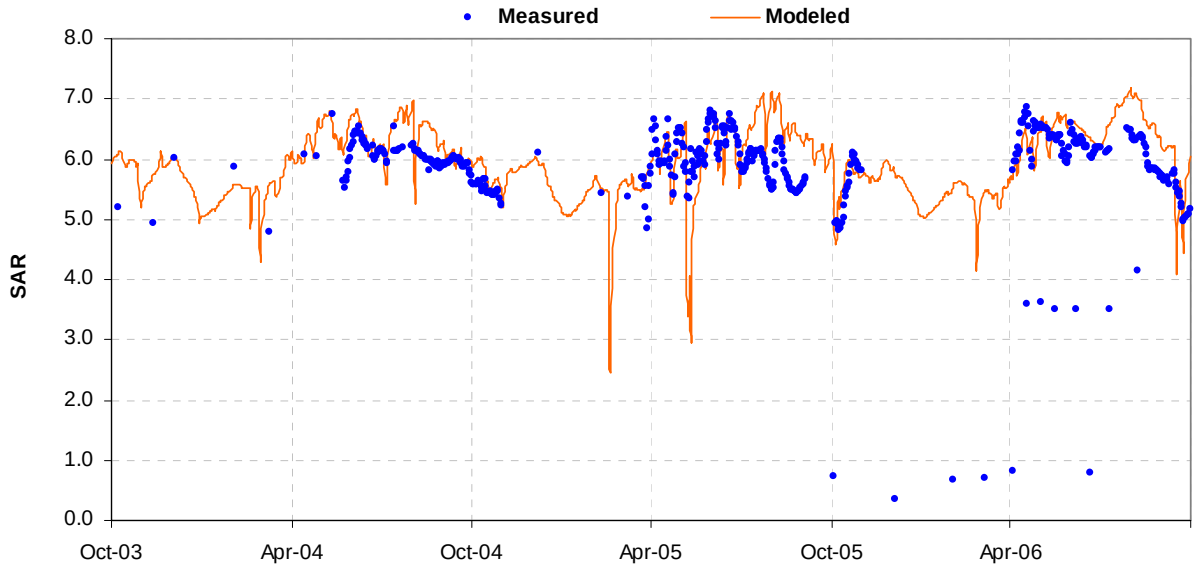

Figure B-101. Time series of SAR data for Otter Creek near Ashland, Montana (USGS Gage 06307740).

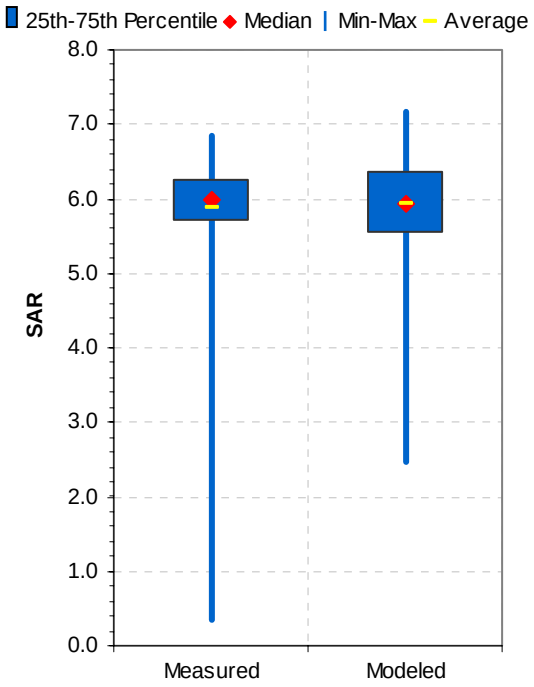

Figure B-102. Distribution of measured and modeled SAR data for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

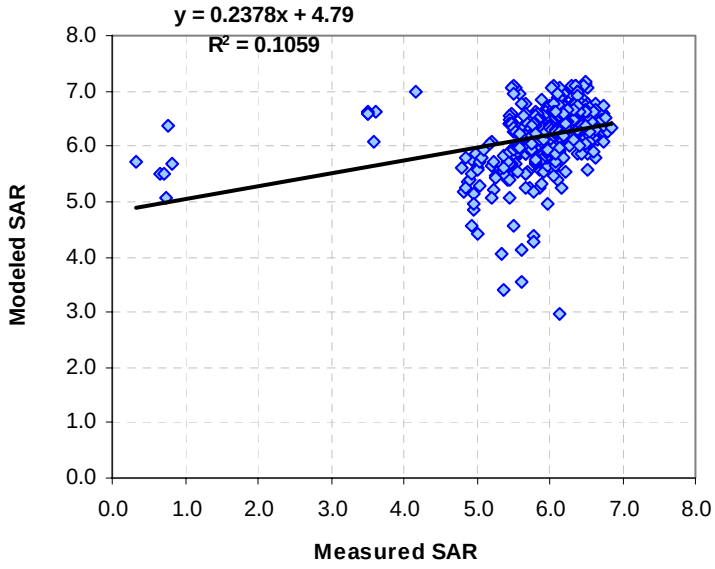

Figure B-103. Observed versus simulated scatter plot of average daily SAR values for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

Table B-19.SAR calibration statistics for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SAR	Average SAR	Median SAR	Average SAR	Median SAR	Average SAR
All Data	6.25	6.19	6.02	5.94	3.9%	4.3%
Growing Season	6.25	6.19	6.02	5.94	3.9%	4.3%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA
April	6.08	6.06	6.14	6.09	-0.9%	-0.4%
May	6.41	6.03	6.17	6.09	3.8%	-1.0%
June	6.39	6.38	6.28	6.22	1.8%	2.5%
July	6.58	6.52	6.07	6.02	8.3%	8.4%
August	6.56	6.59	5.95	5.93	10.2%	11.2%
September	6.00	5.85	5.76	5.68	4.1%	3.0%
October	5.71	5.67	5.48	5.41	4.2%	4.8%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in Otter Creek at Ashland, MT (USGS Gage 06307740). Months with less than 15 observed samples were excluded from this analysis.**

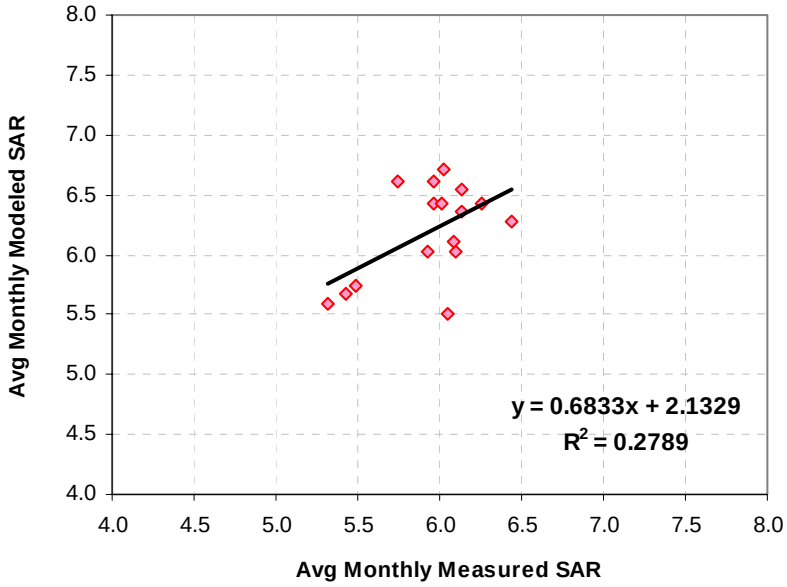

Figure B-104. Observed versus simulated scatter plot of average monthly SAR values for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

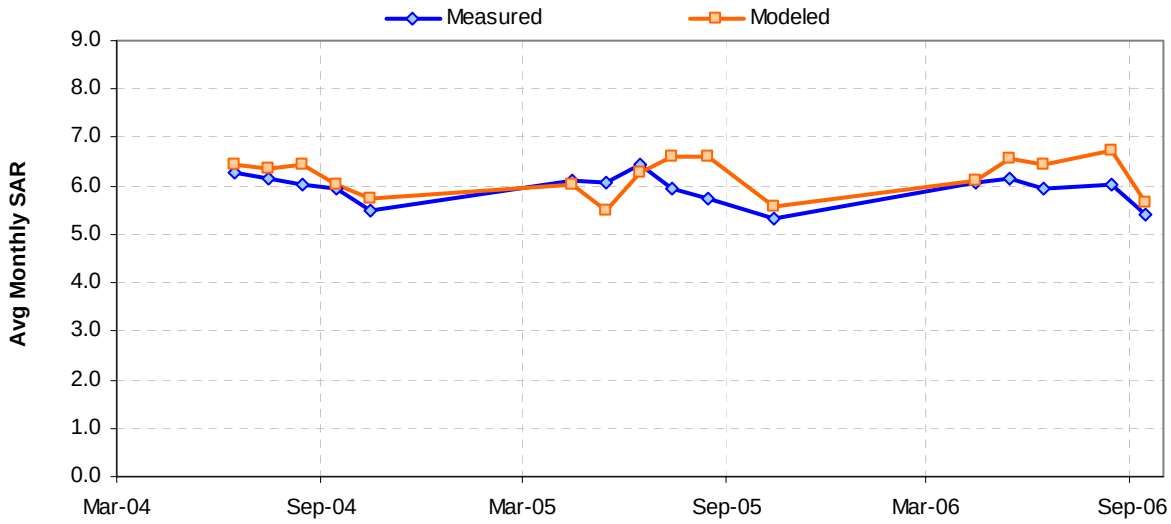

Figure B-105. Time series of average monthly SAR data for Otter Creek at Ashland, Montana (October 1, 2003 to September 30, 2006).

B.9 Pumpkin Creek near Miles City, Montana

USGS gaging station 06308400 (Pumpkin Creek near Miles City, Montana) is located at latitude 46.22834º, longitude -105.69055º (NAD83) in Custer County, Montana, Hydrologic Unit 10090102 (USGS, 2004). The gage elevation is 2,490 feet (NGVD 29), and the gage has a watershed area of 697 square miles. USGS reports a bankfull width of 36 feet and a mean bankfull depth of 2.0 feet for a gage located 7.1 miles downstream of gage 06308400 (USGS, 2004). This gage corresponds to the LSPC modeling pour point for subbasin 1007. The location of the gage is shown in Figure B-1 and photos of the location are shown in Figure B-106.

Figure B-106. Pumpkin Creek near Miles City, Montana (USGS Gage 06308400). Photos by Tetra Tech, Inc and USGS.

B.9.1 Hydrology

Discharge data are available for Pumpkin Creek near Miles City, Montana at USGS gage 06308400. The period of record for flow is from 1972 to 1985, and 2004 to present. The two-year period between October 1, 2004 and September 30, 2006 was selected for calibration at this location. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1989 conditions.
- No flow data were available at this gage between 1990 and 2003.

Daily and monthly average calibration graphs and statistics are provided in Figure B-107, Figure B-108, Figure B-109, Figure B-110, and Table B-20.

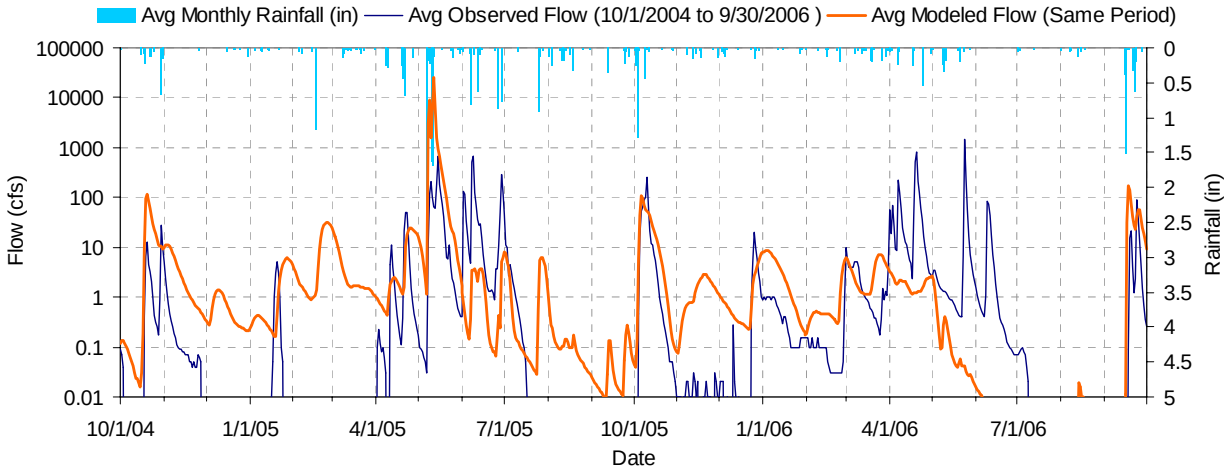

Figure B-107. Time series of hydrologic calibration results (daily mean) for Pumpkin Creek near Miles City, Montana (USGS Gage 06308400).

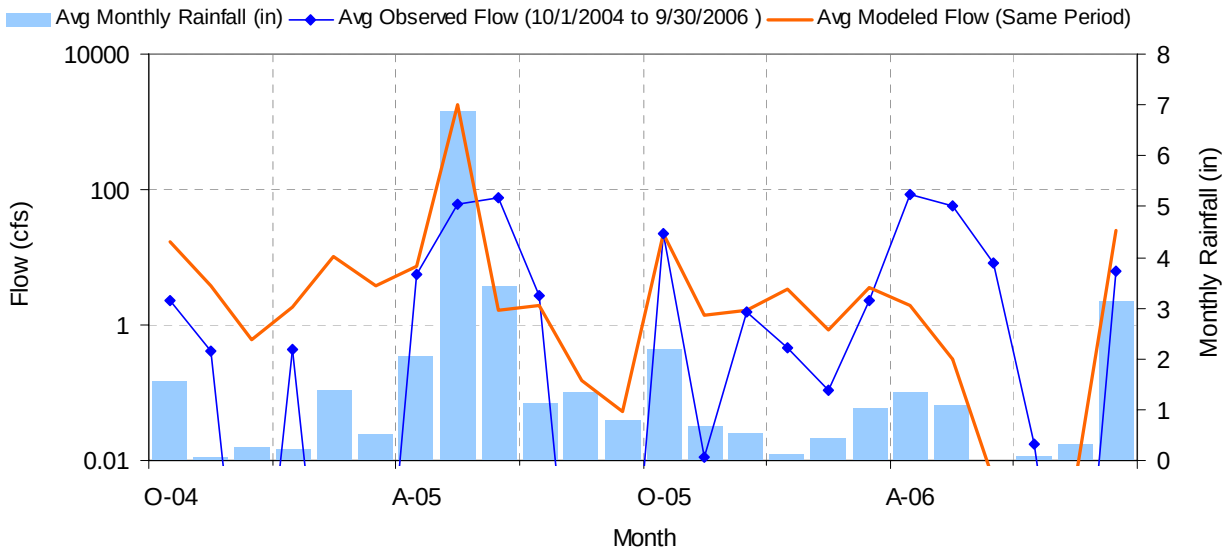

Figure B-108. Time series of hydrologic calibration results (monthly mean) for Pumpkin Creek near Miles City, Montana (USGS Gage 06308400).

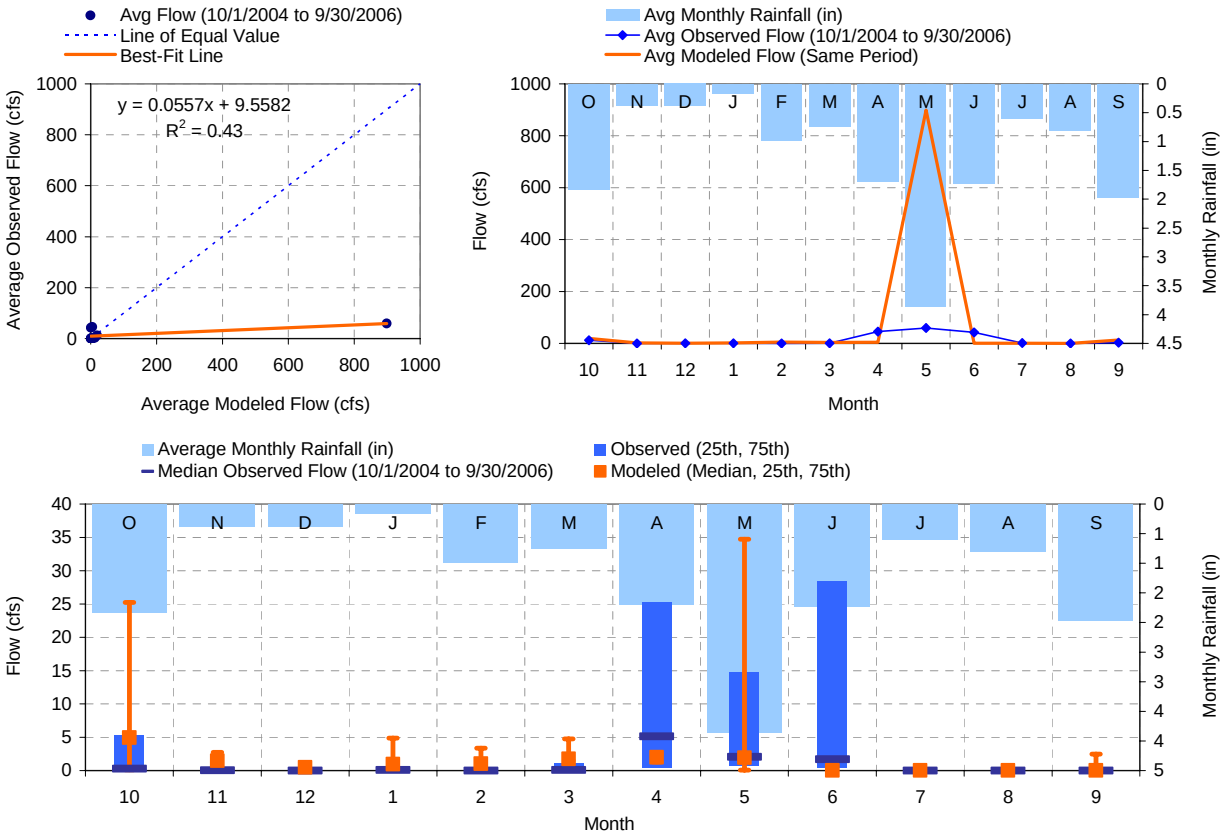

Figure B-109. Composite (average monthly) hydrologic calibration results for Pumpkin Creek near Miles City, Montana (USGS Gage 06308400) (October 1, 2004 to September 30, 2006).

Table B-20. Hydrologic calibration statistics for Pumpkin Creek near Miles City, Montana (USGS Gage 06308400) (October 1, 2004 to September 30, 2006).

	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
Time Period	**Total Volume (acre-feet)**	**Median Discharge (cfs)**	**Average Discharge (cfs)**	**Total Volume (acre-feet)**	**Median Discharge (cfs)**	**Average Discharge (cfs)**	**Total Volume (%)**	**Median Discharge (%)**	**Average Discharge (%)**
All Data	69,415	0.6	47.9	20,269	0.1	14.0	242%	1020%	242%
Growing Season	8,486	0.4	8.7	20,086	0.2	20.7	-58%	115%	-58%
Non-growing Season	60,929	1.2	128.0	183	0.0	0.4	33210%	12365%	33210%
January	7,458	6.6	60.6	54	0.1	0.4	13668%	6493%	13668%
February	32	0.1	0.3	6	0.0	0.1	425%	521%	425%
March	3	0.0	0.0	143	0.1	1.2	-98%	-80%	-98%
April	7,074	0.0	59.4	5,406	5.2	45.4	31%	-100%	31%
May	21	0.1	0.2	7,333	2.1	59.6	-100%	-97%	-100%
June	744	0.8	6.3	5,104	1.7	42.9	-85%	-53%	-85%
July	126	0.6	1.0	172	0.0	1.4	-26%	NA	-26%
August	158	1.0	1.3	0	0.0	0.0	NA	NA	NA
September	245	1.3	2.1	376	0.0	3.2	-35%	NA	-35%
October	116	1.0	0.9	1,552	0.3	12.6	-93%	278%	-93%
November	43,618	27.5	366.5	25	0.0	0.2	175687%	137376%	175687%
December	9,820	5.0	79.9	98	0.0	0.8	9945%	NA	9945%
10% Highest Flows	69,414	0.7	53.3	20,269	0.1	15.1	242%	1347%	253%
10% Lowest Flows	2	0.0	0.0	0	0.1	4.0	NA	-88%	-100%

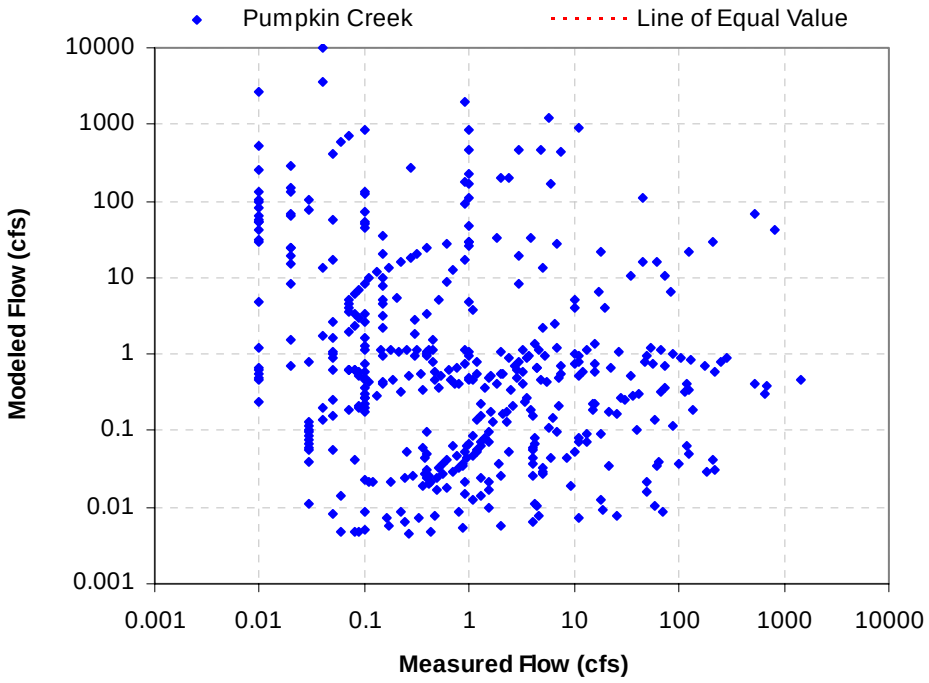

Figure B-110. Observed versus simulated scatter plot of average daily values for Pumpkin Creek near Miles City, Montana (October 1, 2004 to September 30, 2006).

B.9.2 Water Quality

Calcium (Ca), magnesium (Mg), and sodium (Na) were modeled in Pumpkin Creek to supplement the water quality impairment analysis for salinity and sodium adsorption ratio (SAR) (as described in the Assessment Report, DEQ, 2005). Data were collected at USGS Gage 06308400 (Pumpkin Creek near Miles City, Montana) at varying frequencies from 1975 to present. The following sections present a parameter-by-parameter discussion of the water quality calibration for Hanging Woman Creek.

B.9.2.1 Salinity

Salinity data (measured as specific conductance, SC) are available for Pumpkin Creek at USGS Gage 06308400. The period of record at this gage for salinity is 1975 to present. During this period, samples were collected at varying frequencies. Daily data were collected from May 25, 2004 to present. The data collected between June 1, 2004 and September 30, 2006 were used for the salinity calibration. This time period provided 2.25 years of salinity data with some continuous daily data (n=291, 34 percent complete). The fit between model results and observations was best judged both graphically and statistically. Daily and monthly average calibration graphs and statistics are shown in Figure B-111, Figure B-112, Figure B-113, Figure B-114, Figure B-115, and Table B-21.

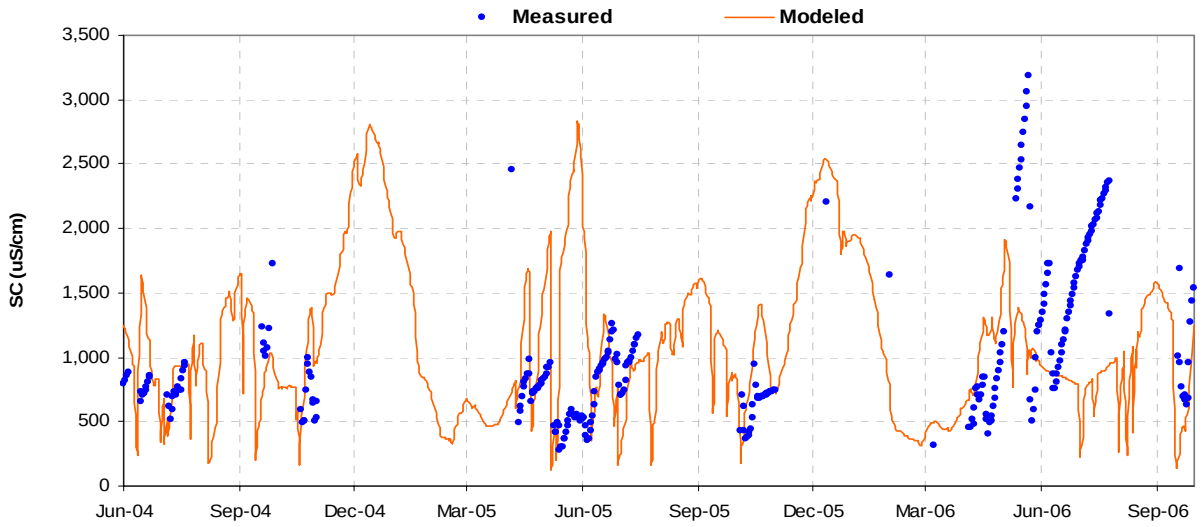

Figure B-111. Time series of salinity data for Pumpkin Creek near Miles City (USGS Gage 06308400).

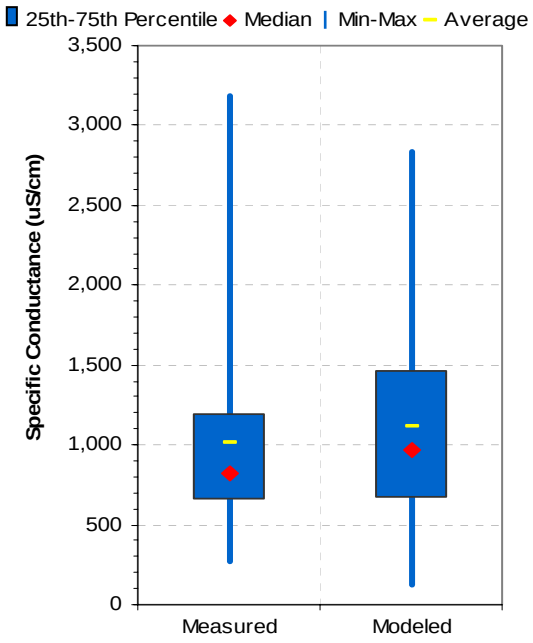

Figure B-112. Distribution of measured and modeled salinity data for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).

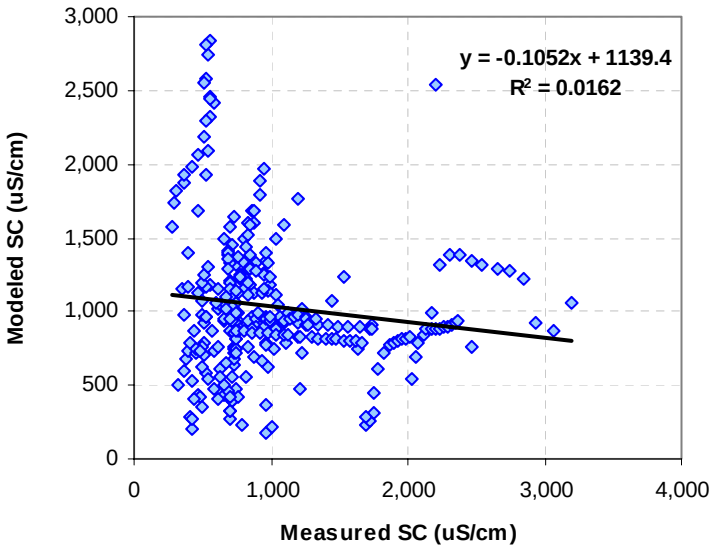

Figure B-113. Observed versus simulated scatter plot of average daily salinity values for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).

Table B-21. Salinity calibration statistics for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).

Time Period	Modeled		Observed		Percent Difference *(Modeled – Observed) / Observed x 100*	
	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (µS/cm)	Average SC (µS/cm)	Median SC (%)	Average SC (%)
All Data	927	1,048	828	1,032	12.0%	1.6%
Growing Season	927	1,048	828	1,032	12.0%	1.6%
Non-growing Season	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA
April	1,149	1,088	736	741	56.1%	47.0%
May	1,527	1,554	670	1,118	127.9%	39.0%
June	865	905	1,009	1,043	-14.2%	-13.2%
July	871	762	1,118	1,380	-22.1%	-44.8%
August	NA	NA	NA	NA	NA	NA
September	NA	NA	NA	NA	NA	NA
October	935	931	690	627	35.5%	48.5%
November	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA

[1]**Observed data consist of daily data collected in Pumpkin Creek near Miles City (USGS Gage 06308400). Months with less than 15 observed samples were excluded from this analysis.**

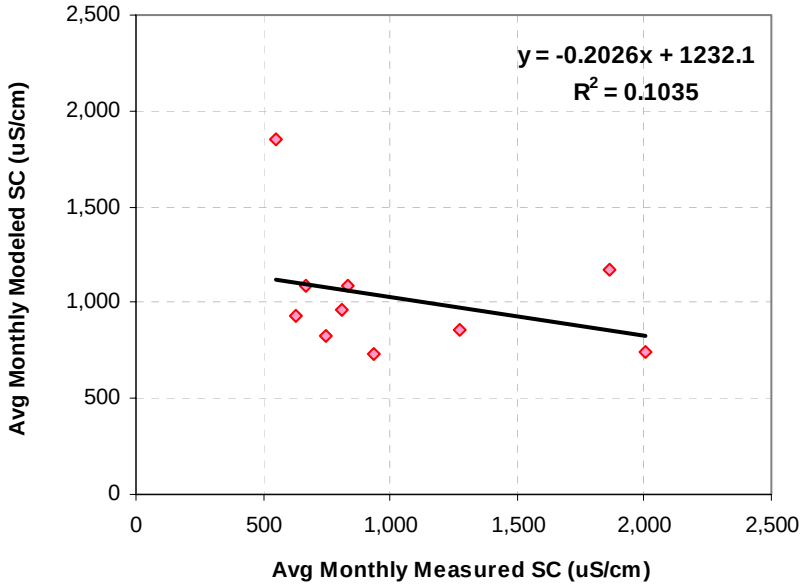

Figure B-114. **Observed versus simulated scatter plot of average monthly salinity values for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).**

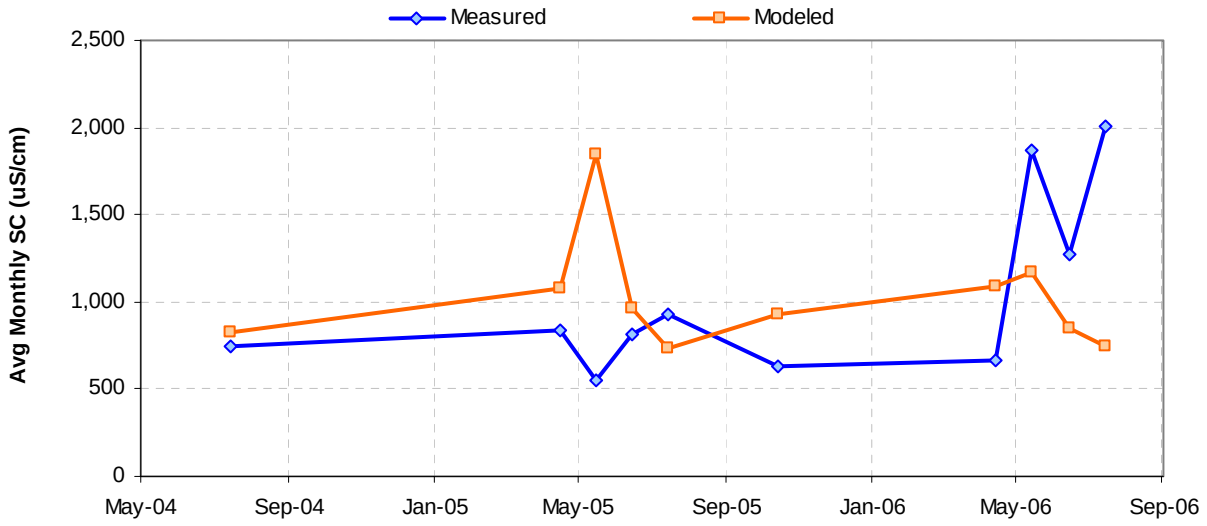

Figure B-115. **Time series of average monthly salinity data for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).**

B.9.2.2 SAR

SAR data are available for Pumpkin Creek at USGS Gage 06308400. The period of record at this gage for salinity is 1975 to present. During this period, monthly samples were obtained between October 1975 and August 1985, and March 2004 to June 2006. Because of the lack of data, it is inappropriate to evaluate the calibration using yearly, monthly, or daily statistics. The primary method for calibrating SAR was a visual inspection of modeled and observed data. The period between March 1, 2004 and June 30, 2006 was chosen as the calibration time period because it contained the most recent available data (n=27). The observed and simulated SAR values for the calibration period at this gage are shown in Figure B-116 and Figure B-117.

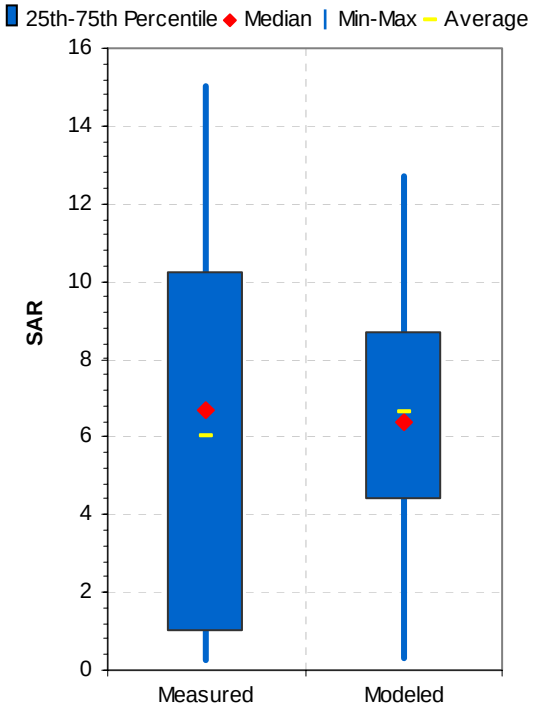

Figure B-116. Distribution of measured and modeled SAR data for Pumpkin Creek near Miles City, Montana (June 1, 2004 to September 30, 2006).

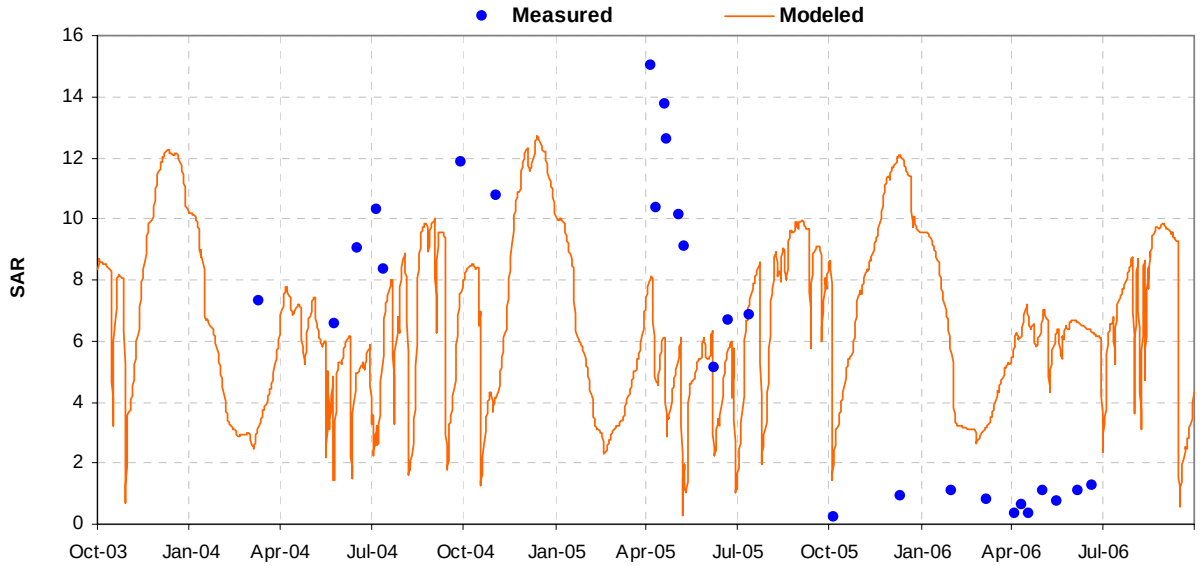

Figure B-117. Time series of SAR data for Pumpkin Creek near Miles City (USGS Gage 06308400).

B.10 High-Altitude Calibration Gages

Several high-altitude USGS gages were used to refine the hydrologic calibration in the Bighorn Mountains. As reported in Section 4.1.1, a majority of the water in the Tongue River watershed originates in the mountains, and obtaining an adequate calibration of this region was important for achieving calibrated results in more downstream segments. USGS gages used for this analysis were Big Goose Creek near Sheridan, Wyoming (06302000), Wolf Creek at Wolf, Wyoming (06299500), Little Goose Creek near Bighorn, Wyoming (06303500), East Fork Big Goose Creek near Bighorn, Wyoming (06300500), and Coney Creek above Twin Lakes near Bighorn, Wyoming (06301480).

USGS maintains long-term continuous flow recorders at all of these gages, but generally only from April 1 to September 30 of each year. Few discharge data were available for October through March, and few water chemistry data were available at the gages. The following sections present the hydrologic calibration results for the five high-altitude USGS gages. No water quality calibration was performed.

B.10.1 Wolf Creek at Wolf, Wyoming

USGS gaging station 06299500 (Wolf Creek at Wolf, Wyoming) is located at latitude 44.77247º, longitude -107.2342º (NAD83) in Sheridan County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 4,525 feet (NGVD 29), and the gage has a watershed area of 38 square miles. No bankfull width or depth information was available. This gage corresponds to the LSPC modeling pour point for subbasin 3070. The location of the gage is shown in Figure B-1.

USGS maintains a continuous flow recorder on Wolf Creek at Wolf, Wyoming from April 1 to September 30 of each year. Data are available from 1945 to present. The period between April 1, 1993 and September 30, 2006 was selected for the hydrologic calibration. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between April 1, 1993 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed.

Daily and monthly average calibration graphs and statistics are provided in Figure B-118, Figure B-119, Figure B-120, Figure B-121, and Table B-22.

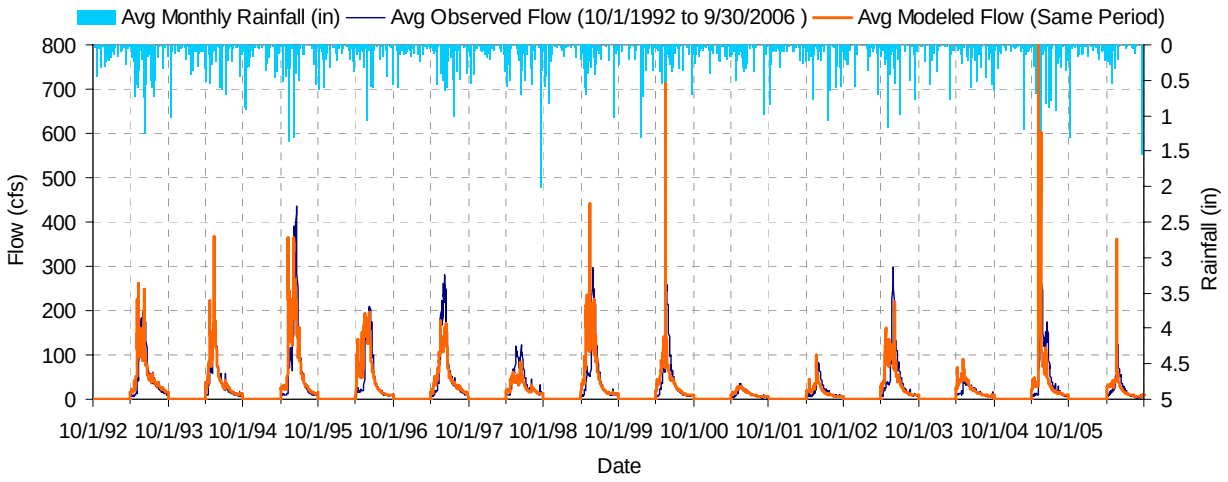

Figure B-118. Time series of hydrologic calibration results (daily mean) for Wolf Creek at Wolf, Wyoming (USGS Gage 06299500).

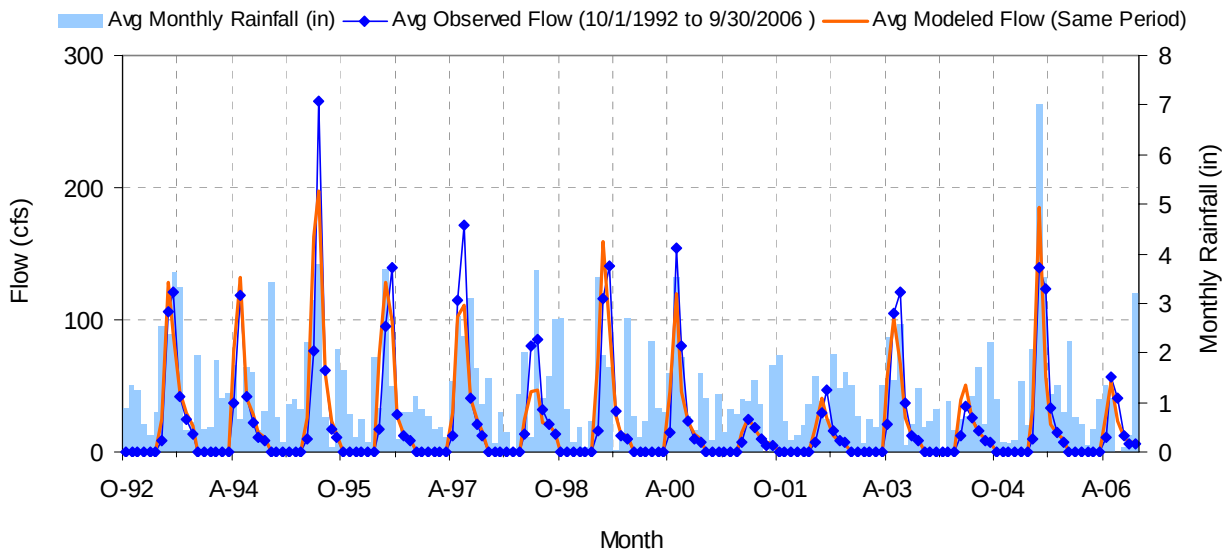

Figure B-119. Time series of hydrologic calibration results (monthly mean) for Wolf Creek at Wolf, Wyoming (USGS Gage 06299500).

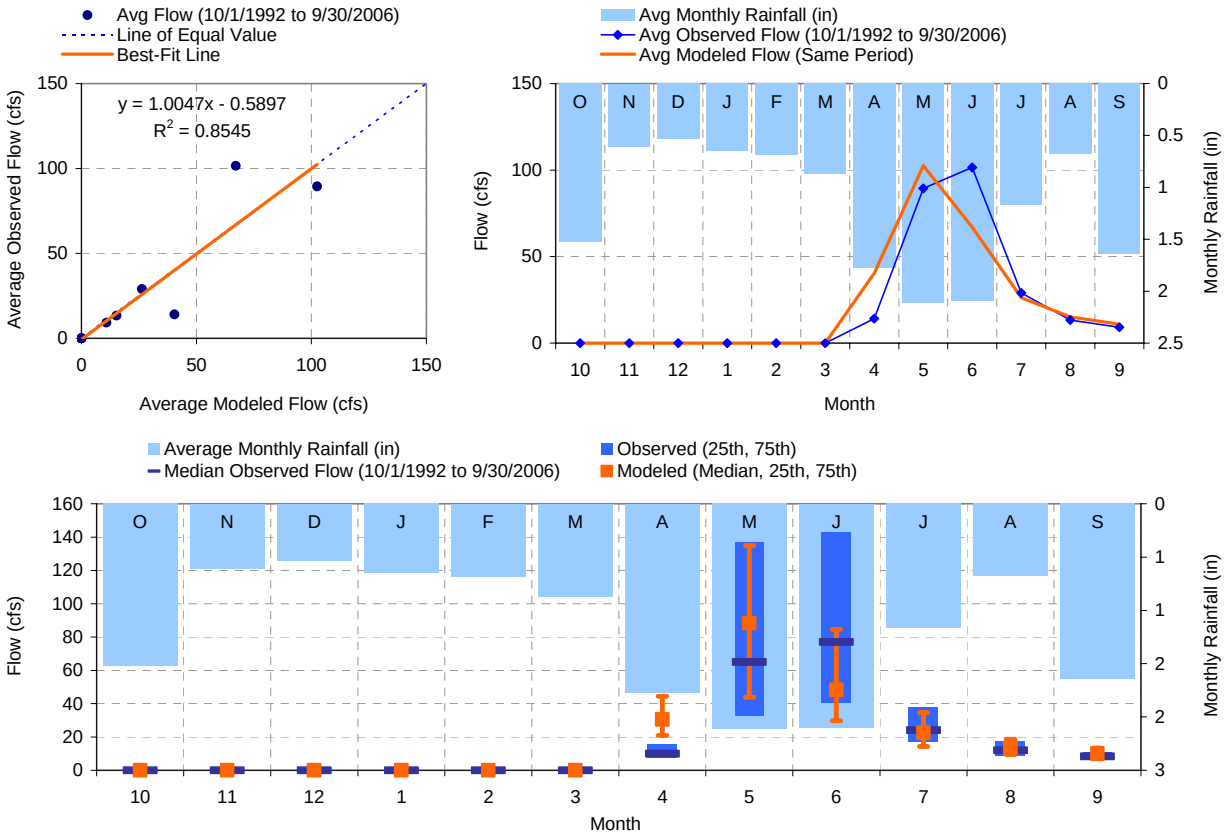

Figure B-120. Composite (average monthly) hydrologic calibration results for Wolf Creek at Wolf, Wyoming (USGS Gage 06299500) (April 1, 1993 to September 30, 2006).

Table B-22. Hydrologic calibration statistics for Wolf Creek at Wolf, Wyoming (USGS Gage 06299500) (April 1, 1993 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	154,577	22	39	157,253	17	39	-1.7%	28.2%	-1.7%
Growing Season	154,577	22	39	157,253	17	39	-1.7%	28.2%	-1.7%
Non-growing Season	NA	NA	NA	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA	NA	NA
April	26,108	33	40	8,466	10	13	208.4%	230.0%	208.4%
May	62,213	71	92	58,492	58	86	6.4%	23.1%	6.4%
June	36,430	45	56	59,060	74	90	-38.3%	-39.3%	-38.3%
July	14,461	19	21	17,230	22	25	-16.1%	-14.5%	-16.1%
August	8,923	12	13	8,250	11	12	8.2%	9.1%	8.2%
September	6,442	9	10	5,754	8	9	11.9%	12.9%	11.9%
October	NA	NA	NA	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA	NA	NA	NA
10% Highest Flows	150,783	26	43	154,318	20	44	-2.3%	31.3%	-2.0%
10% Lowest Flows	3,794	7	7	2,935	6	6	29.3%	23.2%	26.8%

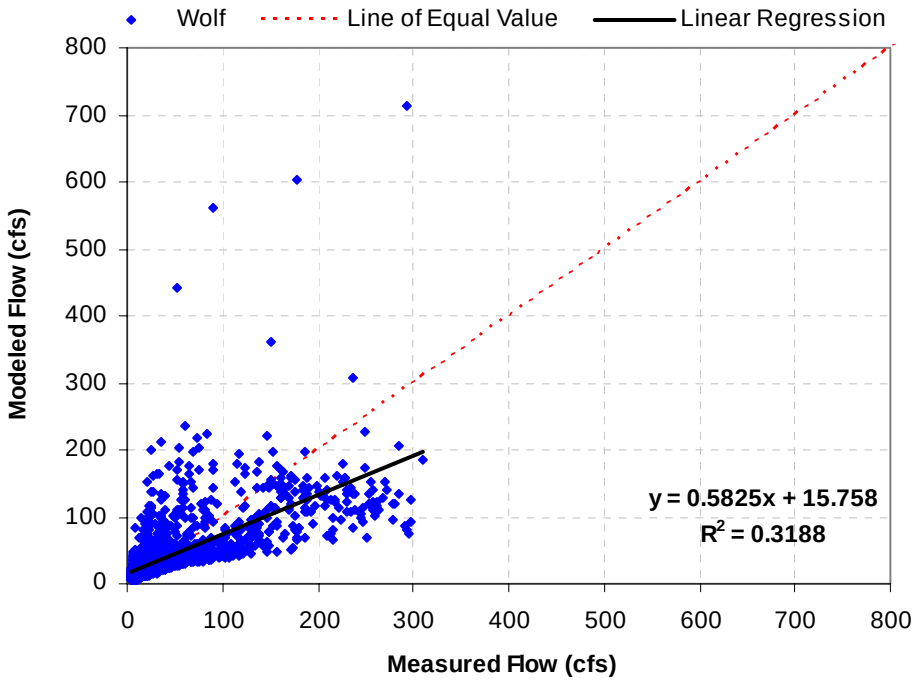

Figure B-121. Observed versus simulated scatter plot of average daily flows for Wolf Creek at Wolf, WY (April 1, 1993 to September 30, 2006).

B.10.2 Big Goose Creek near Sheridan, Wyoming

USGS gaging station 06302000 (Big Goose Creek near Sheridan, Wyoming) is located at latitude 44.70219º, longitude -107.18146º (NAD83) in Sheridan County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 4,505 feet (NGVD 29), and the gage has a watershed area of 120 square miles. No bankfull width or depth information was available. This gage corresponds to the LSPC modeling pour point for subbasin 3046. The location of the gage is shown in Figure B-1.

USGS maintains a continuous flow recorder on Big Goose Creek near Sheridan, Wyoming from April 1 to September 30 of each year. Data are available from 1945 to 2000. The period between April 1, 1993 and September 30, 2000 was selected for the hydrologic calibration. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between April 1, 1993 and September 30, 2000 was used for model calibration because of the dynamic nature of the Tongue River watershed.

Daily and monthly average calibration graphs and statistics are provided in Figure B-122, Figure B-123, Figure B-124, Figure B-125, and Table B-23.

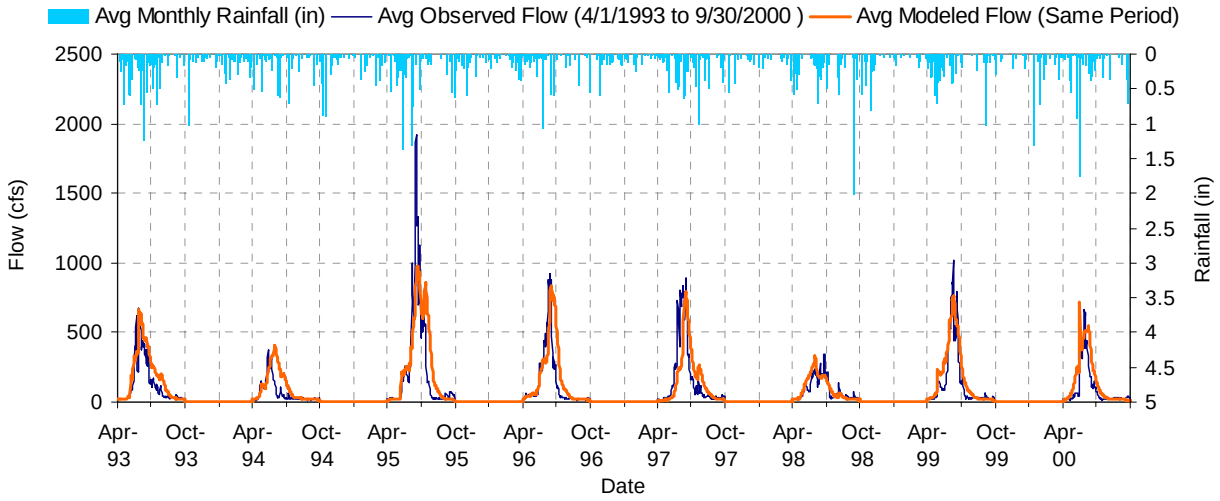

Figure B-122. Time series of hydrologic calibration results (daily mean) for Big Goose Creek near Sheridan, Wyoming (USGS Gage 06302000).

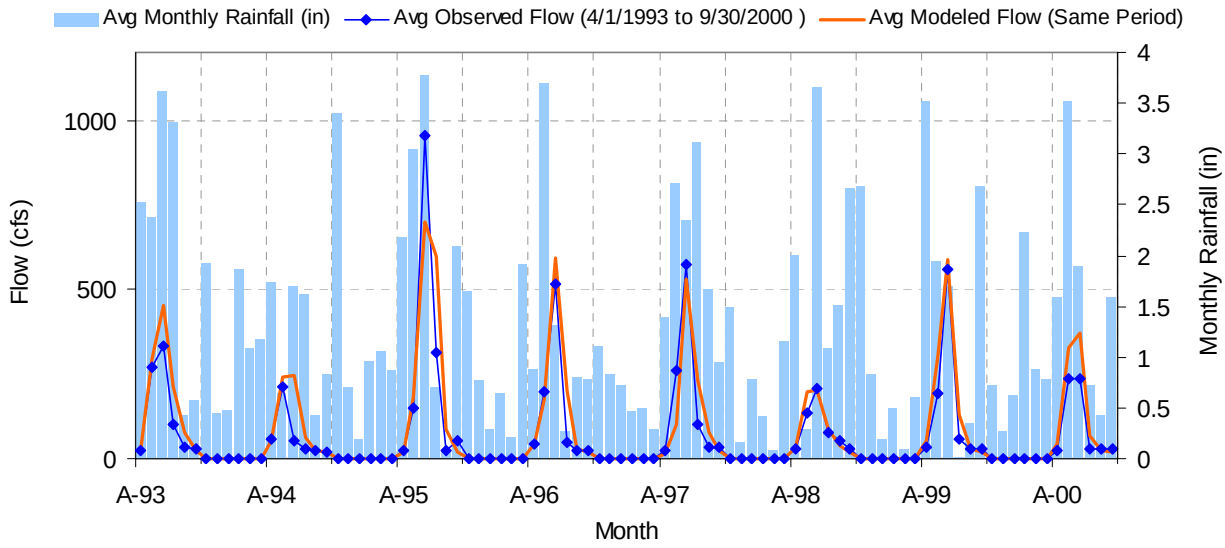

Figure B-123. Time series of hydrologic calibration results (monthly mean) for Big Goose Creek near Sheridan, Wyoming (USGS Gage 06302000).

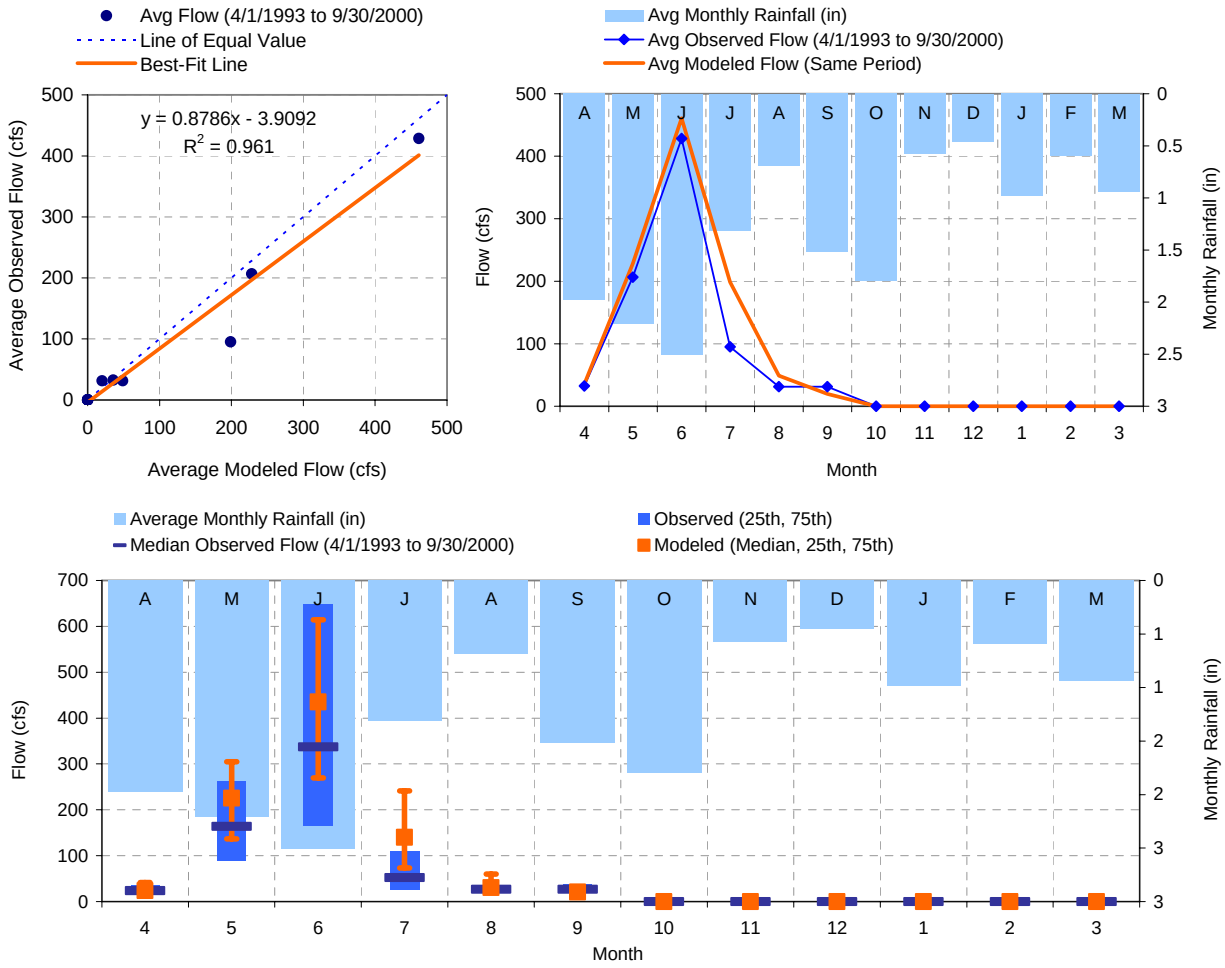

Figure B-124. Composite (average monthly) hydrologic calibration results for Big Goose Creek near Sheridan, Wyoming (USGS Gage 06302000).

Table B-23. Hydrologic calibration statistics for Big Goose Creek near Sheridan, Wyoming (USGS Gage 06302000) (April 1, 1993 to September 30, 2000).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	479,810	65	165	397,897	41	137	20.6%	57.6%	20.6%
Growing Season	479,810	65	165	397,897	41	137	20.6%	57.6%	20.6%
Non-growing Season	NA	NA	NA	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA	NA	NA
April	16,867	24	35	15,367	24	32	9.8%	-0.8%	9.8%
May	112,262	226	228	101,560	164	206	10.5%	37.5%	10.5%
June	219,354	436	461	203,960	338	428	7.5%	29.0%	7.5%
July	97,829	140	199	46,776	53	95	109.1%	166.7%	109.1%
August	24,029	31	49	15,334	27	31	56.7%	13.0%	56.7%
September	9,469	21	20	14,900	27	31	-36.5%	-23.7%	-36.5%
October	NA	NA	NA	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA	NA	NA	NA
10% Highest Flows	479,810	91	182	391,020	49	154	22.7%	85.7%	18.0%
10% Lowest Flows	4,496	16	15	6,878	19	19	-34.6%	-15.8%	-18.0%

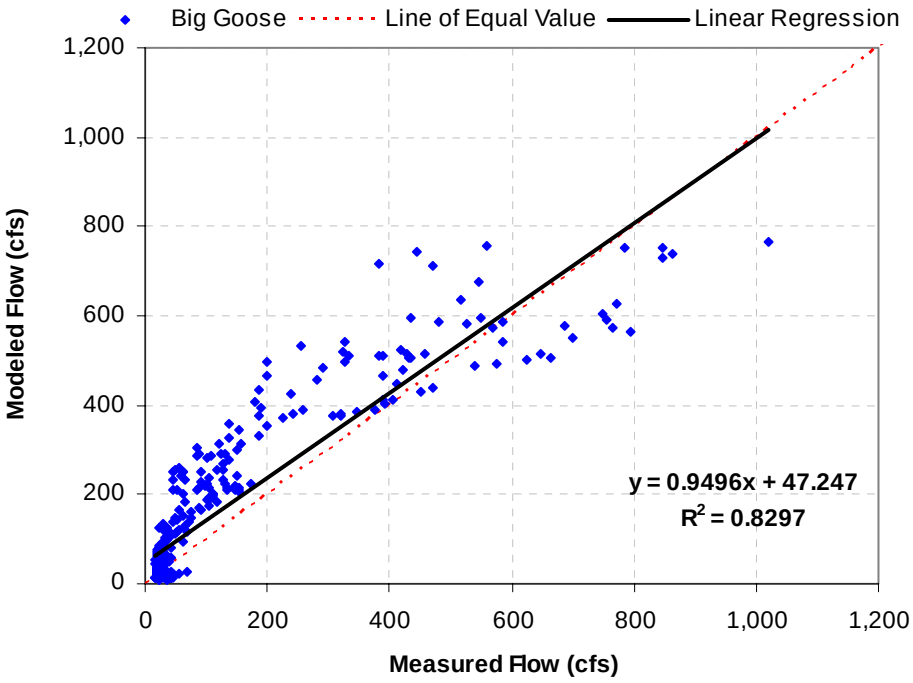

Figure B-125. Observed versus simulated scatter plot of average daily flows for Big Goose Creek near Sheridan, Wyoming (USGS Gage 06302000) (April 1, 1993 to September 30, 2000).

B.10.3 Little Goose Creek near Bighorn, Wyoming

USGS gaging station 06303500 (Little Goose Creek near Bighorn, Wyoming) is located at latitude 44.59608º, longitude -107.04007º (NAD83) in Sheridan County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 4,860 feet (NGVD 29), and the gage has a watershed area of 52 square miles. No bankfull width or depth information was available. This gage corresponds to the LSPC modeling pour point for subbasin 3029. The location of the gage is shown in Figure B-1.

USGS maintains a continuous flow recorder on Little Goose Creek near Bighorn, Wyoming from April 1 to September 30 of each year. Data are available from 1941 to present. The period between April 1, 1993 and September 30, 2006 was selected for the hydrologic calibration. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between April 1, 1993 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed.

Daily and monthly average calibration graphs and statistics are provided in Figure B-126, Figure B-127, Figure B-128, Figure B-129, and Table B-24.

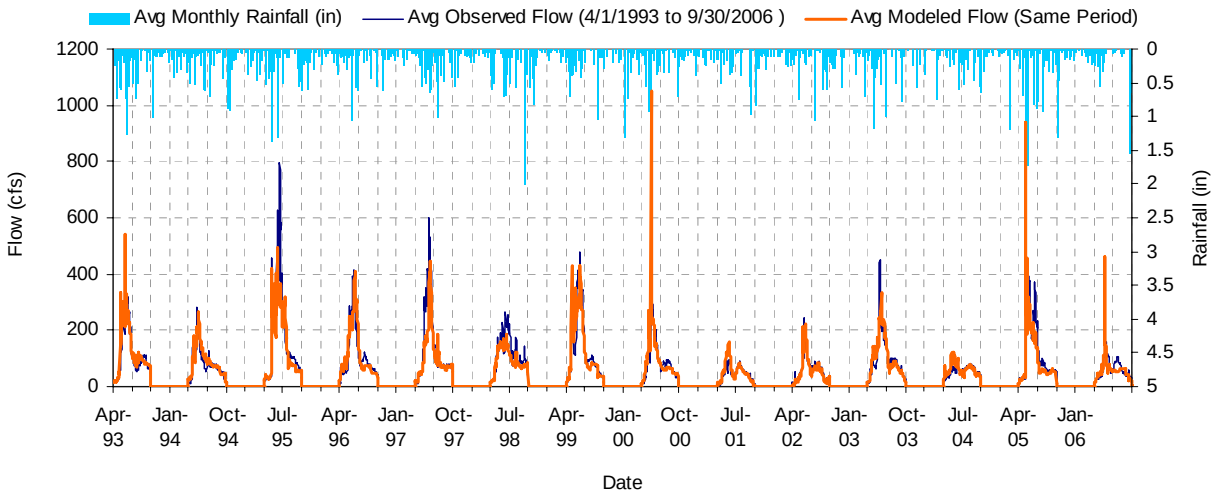

Figure B-126. Time series of hydrologic calibration results (daily mean) for Little Goose Creek near Bighorn, Wyoming (USGS Gage 06303500).

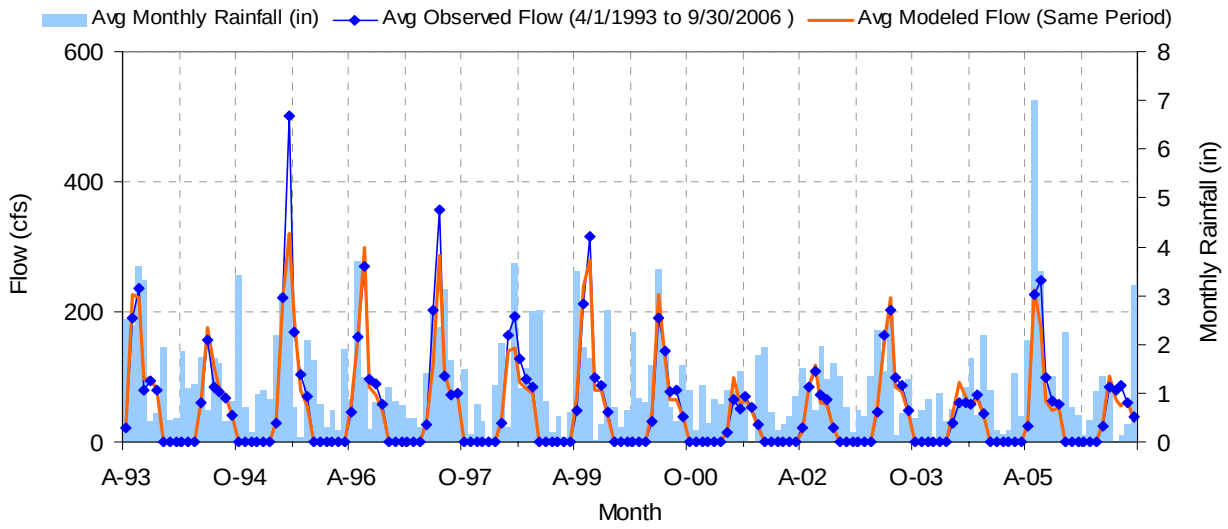

Figure B-127. Time series of hydrologic calibration results (monthly mean) for Little Goose Creek near Bighorn, Wyoming (USGS Gage 06303500).

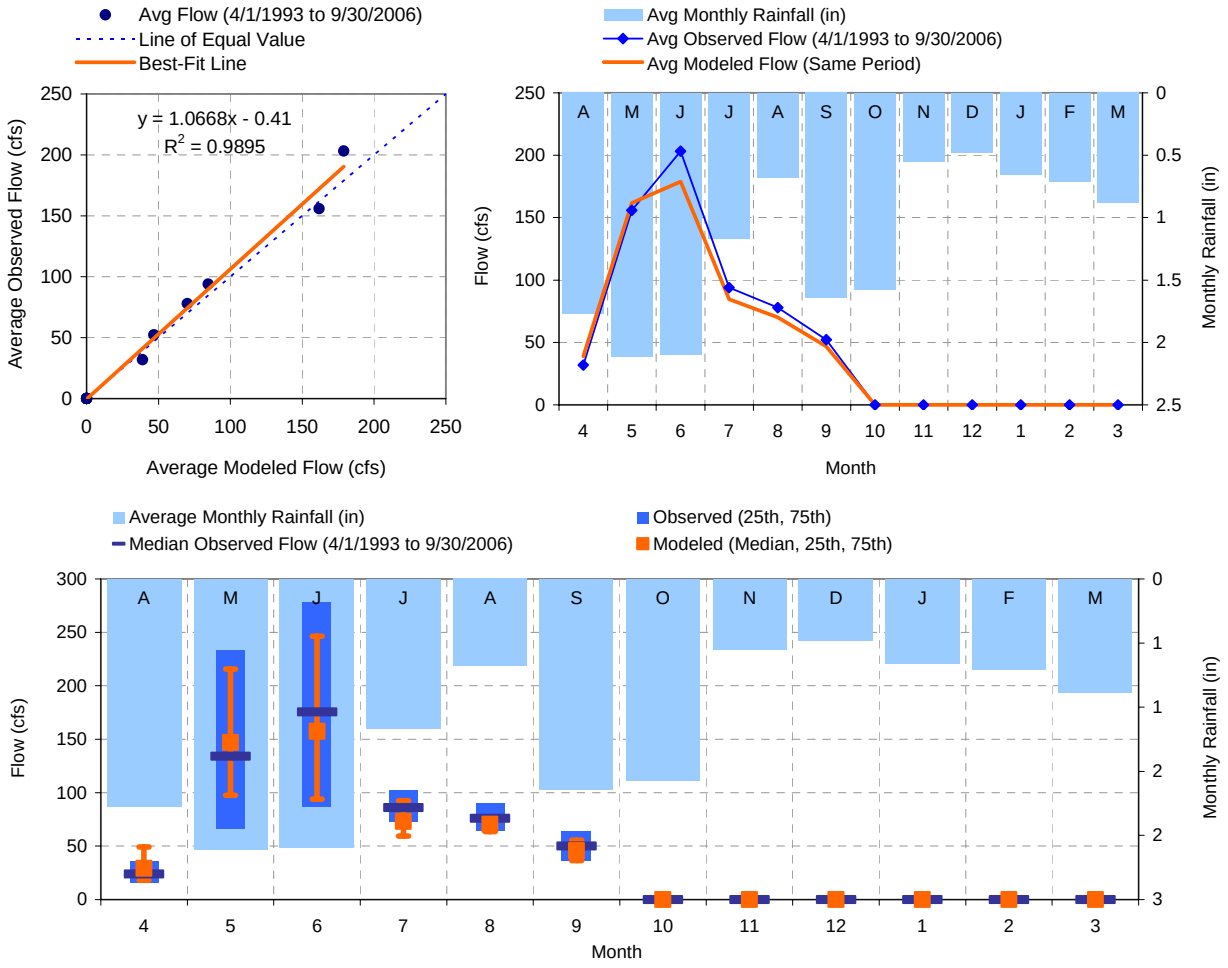

Figure B-128. Composite (average monthly) hydrologic calibration results for Little Goose Creek near Bighorn, Wyoming (USGS Gage 06303500) (April 1, 1993 to September 30, 2006).

Table B-24. Hydrologic calibration statistics for Little Goose Creek near Bighorn, Wyoming (USGS Gage 06303500) (April 1, 1993 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference (Modeled – Observed) / Observed x 100		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	492,972	71	97	521,514	75	103	-5.5%	-5.5%	-5.5%
Growing Season	492,972	71	97	521,514	75	103	-5.5%	-5.5%	-5.5%
Non-growing Season	NA	NA	NA	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA	NA	NA
April	32,436	29	39	26,598	24	32	21.9%	22.1%	21.9%
May	139,320	147	162	134,221	134	156	3.8%	9.7%	3.8%
June	149,009	158	179	169,232	176	203	-11.9%	-10.3%	-11.9%
July	72,815	73	85	80,868	86	94	-10.0%	-14.9%	-10.0%
August	60,349	71	70	67,043	76	78	-10.0%	-7.2%	-10.0%
September	39,042	46	47	43,551	50	52	-10.4%	-8.5%	-10.4%
October	NA	NA	NA	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA	NA	NA	NA
10% Highest Flows	484,278	75	106	512,767	80	112	-5.6%	-6.7%	-5.8%
10% Lowest Flows	8,643	18	17	8,747	17	17	-1.2%	4.1%	1.1%

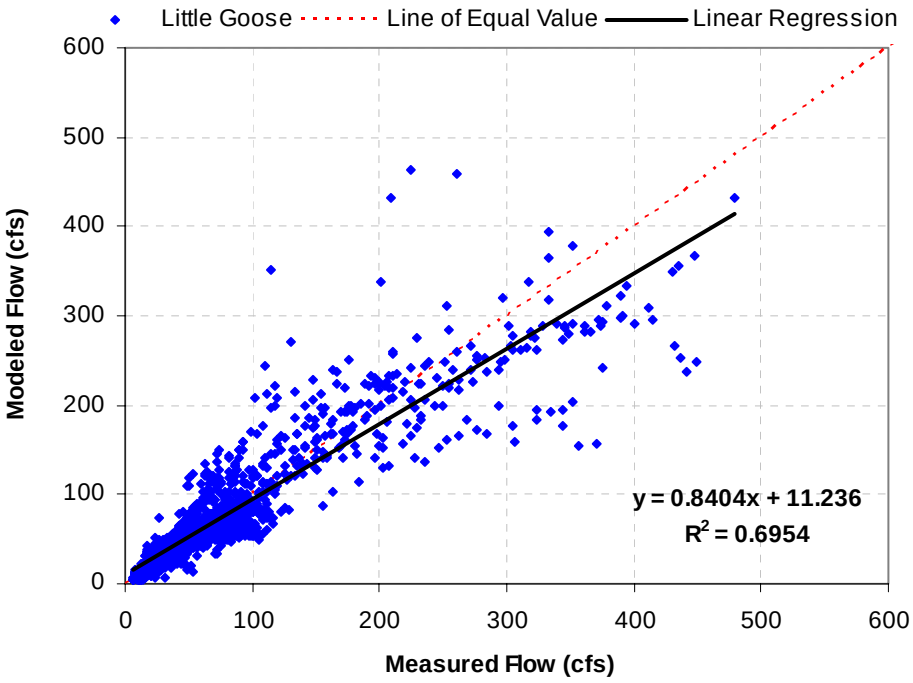

Figure B-129. Observed versus simulated scatter plot of average daily values for Little Goose Creek near Bighorn, Wyoming (USGS Gage 06303500) (April 1, 1993 to September 30, 2006).

B.10.4 East Fork Big Goose Creek near Bighorn, Wyoming

USGS gaging station 06300500 (East Fork Big Goose Creek near Bighorn, Wyoming) is located at latitude 44.53830º, longitude -107.22646º (NAD83) in Johnson County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 8,320 feet (NGVD 29), and the gage has a watershed area of 20 square miles. No bankfull width or depth information was available. This gage corresponds to the LSPC modeling pour point for subbasin 3051. The location of the gage is shown in Figure B-1.

USGS maintains a continuous flow recorder on East Fork Big Goose Creek near Bighorn, Wyoming generally from May 1 to September 30 of each year (gage start dates vary depending on snowpack and weather conditions). Data are available from 1953 to 2002. The period between May 1, 1993 and September 30, 2002 was selected for the hydrologic calibration. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between May 1, 1993 and September 30, 2002 was used for model calibration because of the dynamic nature of the Tongue River watershed.

Daily and monthly average calibration graphs and statistics are provided in Figure B-130, Figure B-131, Figure B-132, Figure B-133, and Table B-25.

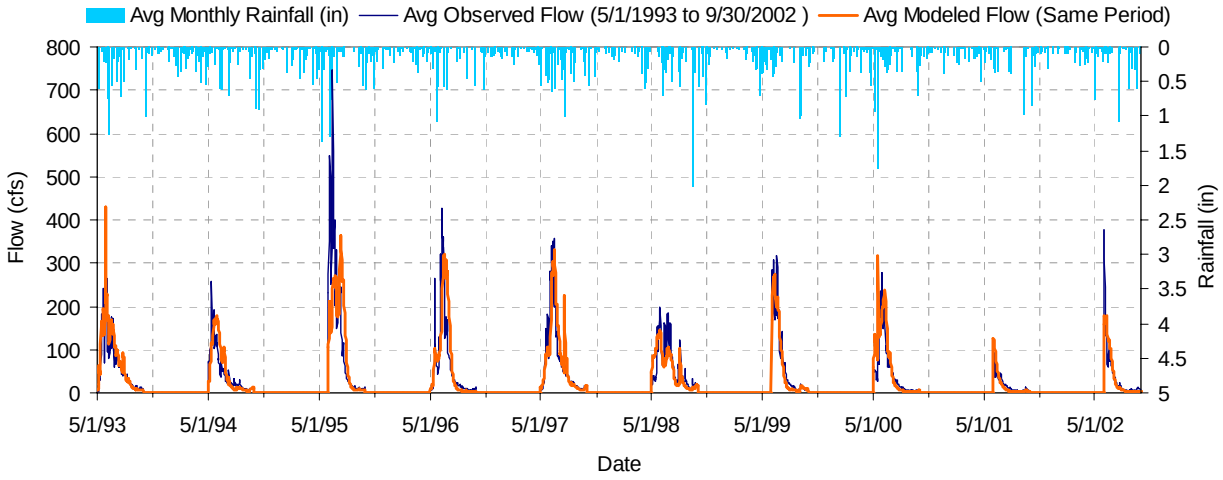

Figure B-130. Time series of hydrologic calibration results (daily mean) for East Fork Big Goose Creek near Bighorn, Wyoming (USGS Gage 06300500).

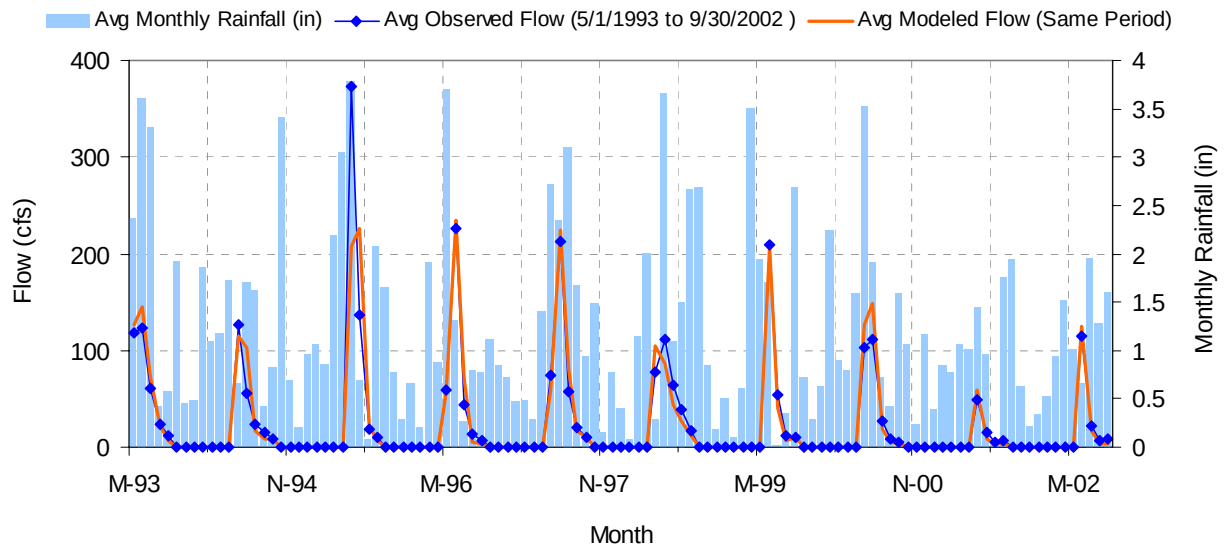

Figure B-131. Time series of hydrologic calibration results (monthly mean) for East Fork Big Goose Creek near Bighorn, Wyoming (USGS Gage 06300500).

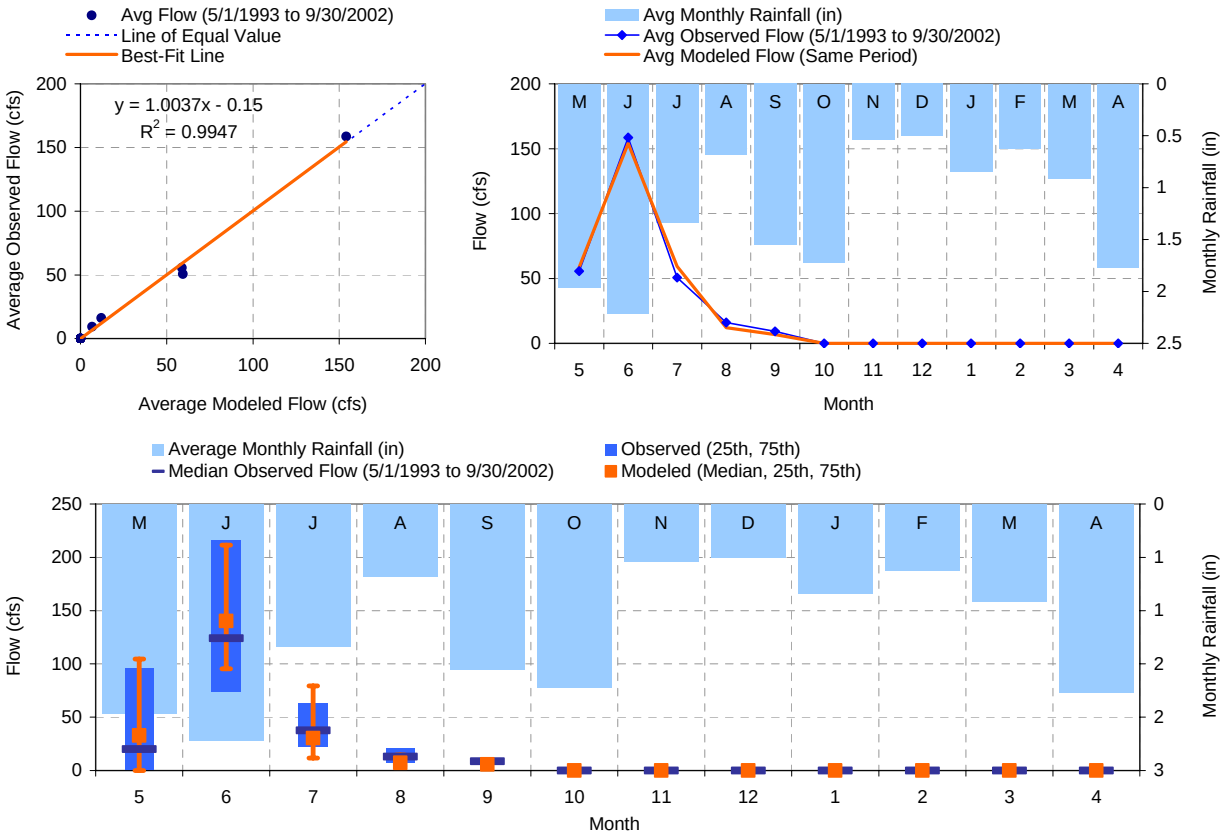

Figure B-132. Composite (average monthly) hydrologic calibration results for East Fork Big Goose Creek near Bighorn, Wyoming (USGS Gage 06300500) (May 1, 1993 to September 30, 2002).

Table B-25. Hydrologic calibration statistics for East Fork Big Goose Creek near Bighorn, Wyoming (USGS Gage 06300500) (May 1, 1993 to September 30, 2002).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	175,784	20	63	175,197	25	63	0.3%	-21.7%	0.3%
Growing Season	175,784	20	63	175,197	25	63	0.3%	-21.7%	0.3%
Non-growing Season	NA	NA	NA	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA	NA	NA
April	NA	NA	NA	NA	NA	NA	NA	NA	NA
May	36,166	95	98	34,234	75	93	5.6%	27.5%	5.6%
June	91,680	140	154	94,397	124	159	-2.9%	13.2%	-2.9%
July	36,497	30	59	31,177	38	51	17.1%	-19.1%	17.1%
August	7,425	7	12	9,868	13	16	-24.8%	-45.5%	-24.8%
September	4,017	6	7	5,521	9	9	-27.2%	-34.4%	-27.2%
October	NA	NA	NA	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA	NA	NA	NA
10% Highest Flows	174,879	29	70	173,779	32	69	0.6%	-9.4%	0.4%
10% Lowest Flows	905	3	3	1,417	5	5	-36.1%	-36.1%	-34.8%

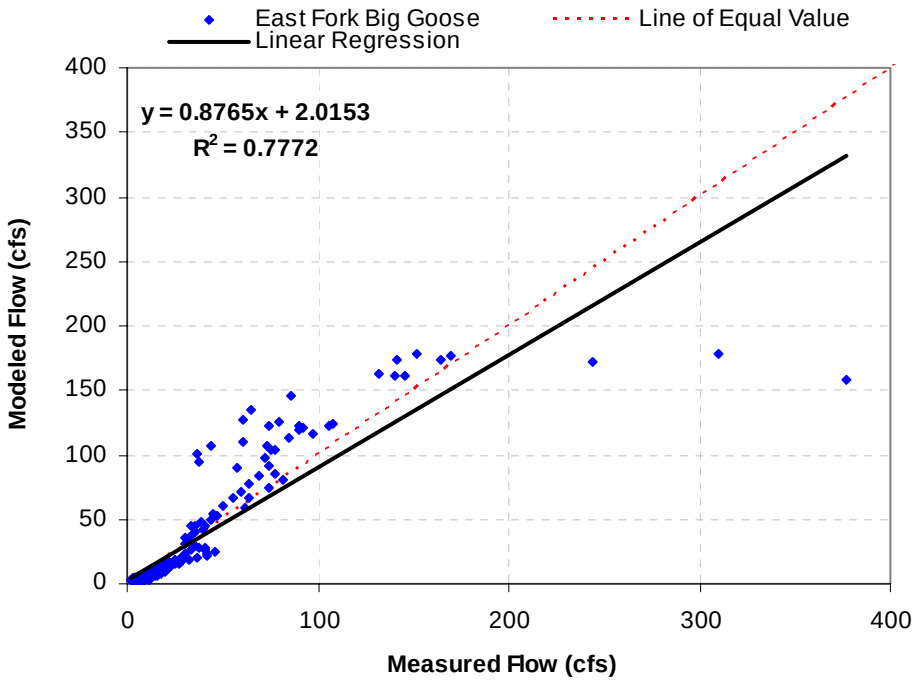

Figure B-133. Observed versus simulated scatter plot of average daily values for East Fork Big Goose Creek near Bighorn, Wyoming (USGS Gage 06300500) (May 1, 1993 to September 30, 2002).

B.10.5 Coney Creek above Twin Lakes near Bighorn, Wyoming

USGS gaging station 06301480 (Coney Creek above Twin Lakes near Bighorn, Wyoming) is located at latitude 44.60136º, longitude -107.31758º (NAD83) in Sheridan County, Wyoming, Hydrologic Unit 10090101 (USGS, 2006). The gage elevation is 8,690 feet (NGVD 29), and the gage has a watershed area of 3.4 square miles. No bankfull width or depth information was available. This gage corresponds to the LSPC modeling pour point for subbasin 3060. The location of the gage is shown in Figure B-1.

USGS maintains a continuous flow recorder on East Fork Big Goose Creek near Bighorn, Wyoming generally from May 1 to September 30 of each year. Data are available from 1990 to present. The period between May 1, 1993 and September 30, 2006 was selected for the hydrologic calibration. This period was selected for several reasons:

- The limiting factor in running the LSPC model was weather data. During model setup, the SNOTEL weather stations only had weather data available from October 1, 1989 to September 30, 2006. These weather gages are necessary for running the LSPC model, and therefore the model could only be calibrated to post-1990 conditions.
- At least one year (and preferably three years) is recommended for model initialization to remove potential effects of initial model conditions (e.g., snowpack, stream stage, precipitation).
- The entire period between May 1, 1993 and September 30, 2006 was used for model calibration because of the dynamic nature of the Tongue River watershed.

Daily and monthly average calibration graphs and statistics are provided in Figure B-134, Figure B-135, Figure B-136, Figure B-137, and Table B-26.

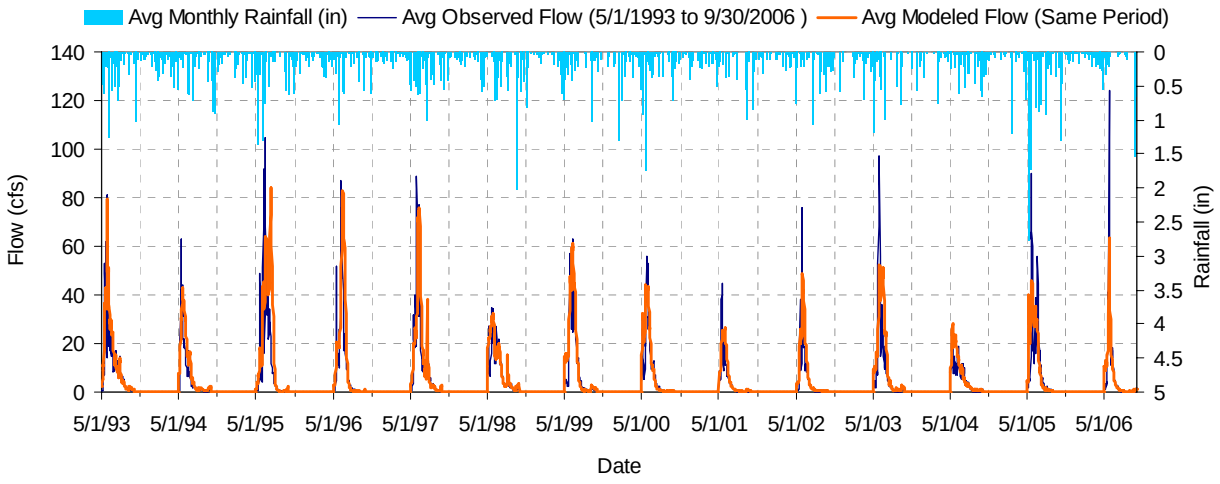

Figure B-134. Time series of hydrologic calibration results (daily mean) for Coney Creek above Twin Lakes (USGS Gage 06301480).

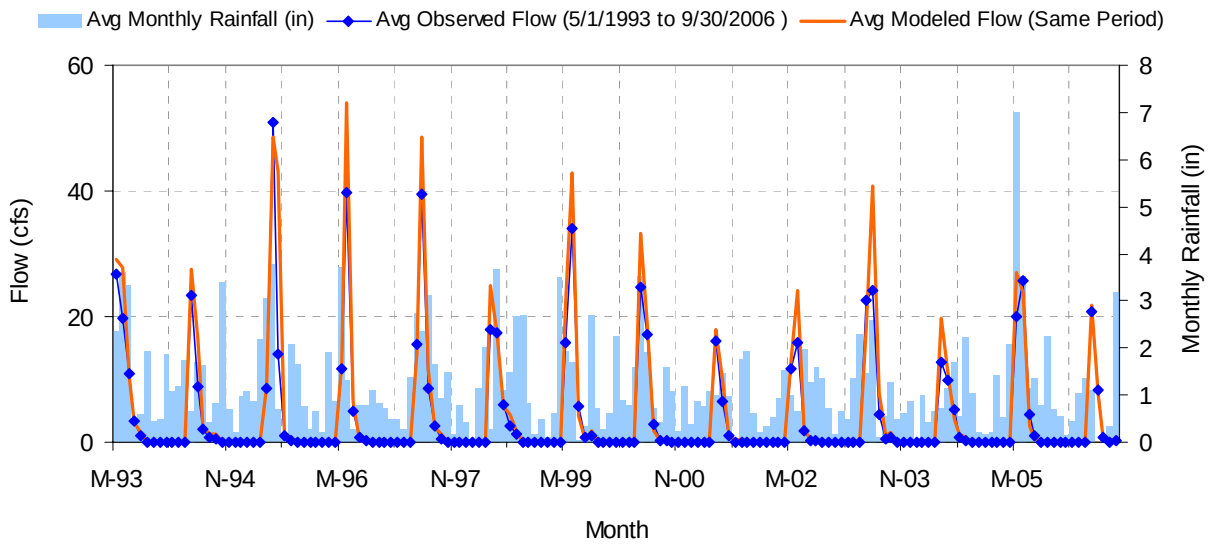

Figure B-135. Time series of hydrologic calibration results (monthly mean) for Coney Creek above Twin Lakes (USGS Gage 06301480).

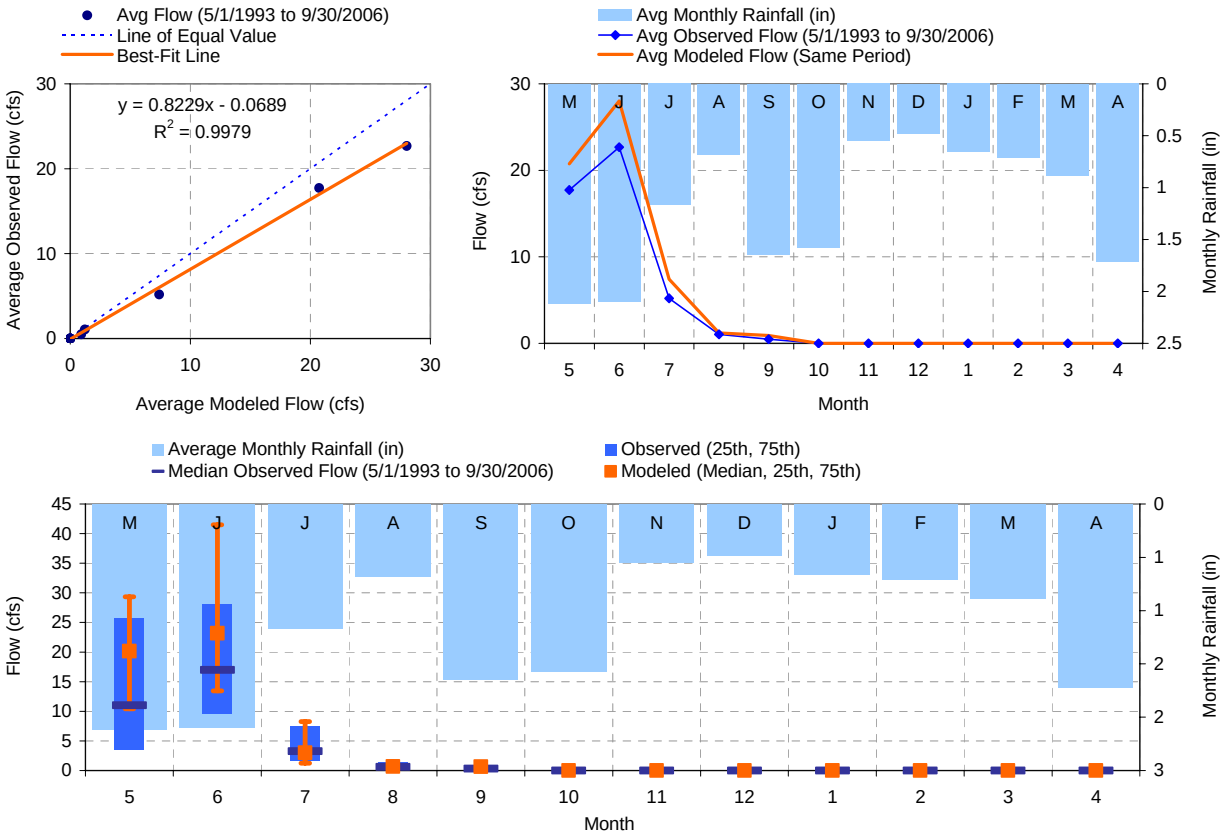

Figure B-136. Composite (average monthly) hydrologic calibration results for Coney Creek above Twin Lakes (USGS Gage 06301480) (May 1, 1993 to September 30, 2006).

Table B-26.Hydrologic calibration statistics for Coney Creek above Twin Lakes near Bighorn, Wyoming (USGS Gage 06301480) (May 1, 1993 to September 30, 2006).

Time Period	MODELED			OBSERVED			Percent Difference *(Modeled – Observed) / Observed x 100*		
	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (acre-feet)	Median Discharge (cfs)	Average Discharge (cfs)	Total Volume (%)	Median Discharge (%)	Average Discharge (%)
All Data	49,389	3.17	11.62	39,946	2.60	9.40	23.6%	21.8%	23.6%
Growing Season	49,389	3.17	11.62	39,946	2.60	9.40	23.6%	21.8%	23.6%
Non-growing Season	NA	NA	NA	NA	NA	NA	NA	NA	NA
January	NA	NA	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA	NA	NA
April	NA	NA	NA	NA	NA	NA	NA	NA	NA
May	17,856	20.15	20.74	15,249	11.00	17.71	17.1%	83.2%	17.1%
June	23,345	23.19	28.02	18,895	17.00	22.68	23.5%	36.4%	23.5%
July	6,383	2.99	7.42	4,476	3.25	5.20	42.6%	-7.9%	42.6%
August	1,043	0.68	1.21	911	0.62	1.06	14.6%	10.5%	14.6%
September	762	0.65	0.92	415	0.32	0.50	83.6%	102.7%	83.6%
October	NA	NA	NA	NA	NA	NA	NA	NA	NA
November	NA	NA	NA	NA	NA	NA	NA	NA	NA
December	NA	NA	NA	NA	NA	NA	NA	NA	NA
10% Highest Flows	49,304	4.64	12.90	39,907	3.60	10.50	23.5%	28.8%	22.9%
10% Lowest Flows	86	0.21	0.20	39	0.09	0.09	117.9%	130.8%	128.1%

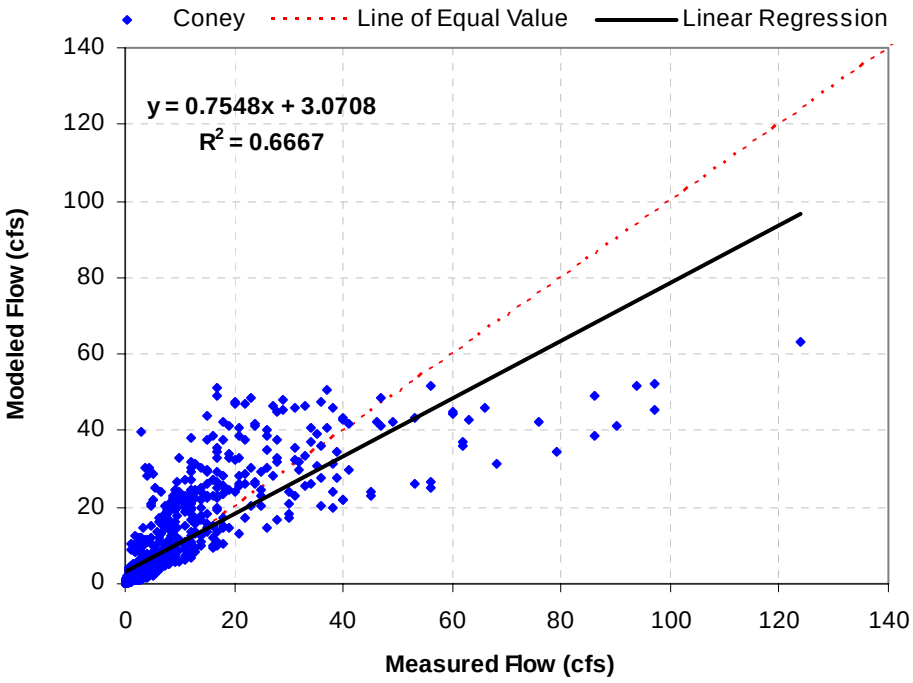

Figure B-137. Observed versus simulated scatter plot of average daily values for Coney Creek above Twin Lakes (USGS Gage 06301480) (May 1, 1993 to September 30, 2006).

B.11 References

DNRC. 2004. DNRC Water Resources Division Annual Report – 2004. Montana Department of Natural Resources and Conservation. Helena, Montana. Available online at http://dnrc.mt.gov/About_Us/publications/2004/wrd.pdf (accessed February 26, 2007).

USEPA. 2007. Water Quality Assessment for the Tongue River Watershed, Montana. U.S. Environmental Protection Agency, Montana Operation Office. Helena, Montana.

USGS. 2004. Channel-Morphology Data for the Tongue River and Selected Tributaries, Southeastern Montana, 2001-02. U.S. Geological Survey Open-File Report 2004-1260. Helena, Montana.

USGS. 2006. National Water Information System [Online]. U.S. Geological Survey. Reston, Virginia. Available at http://waterdata.usgs.gov/nwis.